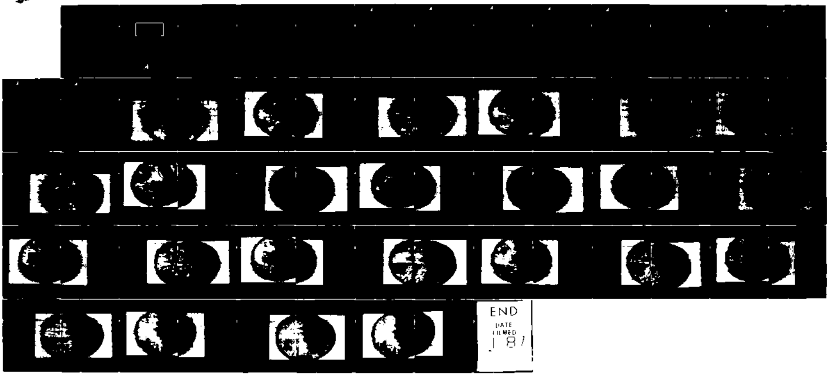
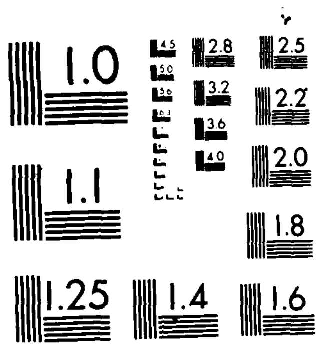
AD-A174 037 AUTOMATED ULTRASONIC INSPECTION OF ARAMID (KEVLAR) 1/1
COMPOSITE PASGT HELMETS FEASIBILITY STUDY(U)
AUTOMATION/SPERRY CHATSWORTH CA D R KAMMERER 02 JUN 86
UNCLASSIFIED TR-86-1 DLA900-86-M-2929 F/G 14/2 NL





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SECURITY CLASSIFICATION OF THIS PAGE

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FIELD	GROUP	SUB-GROUP	Composites - Nondestructive Test - Aramid - Kevlar - Ultrasonics - Inspection

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

Study was conducted to determine feasibility of using ultrasonic nondestructive inspection on compression molded aramid (Kevlar) composite helmets. Results indicated detection capability for internal discontinuities voids & delaminations. Detection of number of layers of aramid does not show much promise.

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(1)

TR 86-1

AUTOMATED ULTRASONIC INSPECTION OF ARAMID (KEVLAR) COMPOSITE PASGT HELMETS FEASIBILITY STUDY

UNITED STATES DEFENSE LOGISTICS AGENCY
DEFENSE ELECTRONICS SUPPLY CENTER
DAYTON, OHIO
CONTRACT NO. DLA900-86-M-Z929
JUNE 2, 1986

Written by

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Field Applications Engineer

AUTOMATION/SPERRY, a unit of Qualcorp
Chatsworth, California
U.S.A.

1986

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A UNIT OF QUALCORP

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1.0 INTRODUCTION

This study was conducted to determine the feasibility of using ultrasonic non-destructive inspection on compression molded aramid (Kevlar) Paratrooper and Support Ground Troop (PASGT) helmets. The present destructive testing method (ballistic) has been determined to be inadequate and costly.

In order to determine the feasibility of using ultrasonic NDT to inspect these PASGT helmets, (6) sample helmet shells were provided to Automation/Sperry by the Defense Logistics Agency. These test samples were representative of production helmets with the exception of their configuration (top of helmet crown only) and internal, artificially manufactured defects.

The objective of this evaluation was to qualify the acoustical attenuation characteristics of the (19) ply kevlar lay-up. Computerized Ultrasonic attenuation measurements in the form of numeric symbols are provided in a C-scan format to substantiate the acoustic properties of the test samples. Several ultrasonic techniques were explored to identify the most reliable and practical method that could be used to meet production inspection requirements.

2.0 SUMMARY OF RESULTS

The (6) PASGT helmet samples were evaluated using the Squirter Thru-Transmission method of Ultrasonic Inspection. (24) Computerized Data Acquisition plots are presented in the test data section of this report. All plots were generated in a plan view or "C-Scan" format of the PASGT samples.

Using either conventional Ultrasonic "Pulse-echo" or "Reflector Plate" techniques to examine the PASGT samples was not feasible. No results were attainable due to the excessive acoustical attenuation of the (19) layer kevlar material. It is suspected that the compression mold process yields non-uniform pressure distribution/resin flow and therefore a very acoustically non-uniform structure. The overall acoustical attenuation within each sample varied over 30 dB.

3.0 CONCLUSIONS

Low frequency, ultrasonic squirter thru-transmission inspection can be applied to examine PASGT helmets for their acoustical attenuation characteristics. Detection of internal discontinuities, voids, delaminations, etc. is feasible. Detection of ply lay-up attenuation differences (18 ply versus 19 plys) does not show much promise due to the overall acoustical attenuation variation over the total helmet area. Real-Time Radiography inspection as described in TR-86-2 would be a more feasible approach to detecting differences in ply number and orientation.

Further work must be done to assist in development of acceptable Ultrasonic reference standards.

4.0 EQUIPMENT

* US-542S MIDUS/TM COMPUTER CONTROLLED ULTRASONIC SCANNING SYSTEM With US-874a Water Squirters

  This dedicated, microprocessor based scanning system provided the high speed motion control after being "taught" a profile to Scan/Index the Ultrasonic transducers.

* US-960 INTELLIGENT PLOTTER

  The US-960 micro-computer based data acquisition system was used to acquire and digitize the ultrasonic data. Once each helmet sample had been inspected, the data was recalled to provide an "Electronic Rescan".

* S-80 Reflectoscope
  PR-4R Remote Pulser/Receiver with a 60DB dynamic range logarithmic amplifier
  GT-1 Gate Module with 0-5 VDC fast analog output

  The S-80 Ultrasonic instrument pulsed the transducer, amplified its' ultrasonic received signal and provided the US-960 with a gated, peak detected analog signal.

* DM-2 36DB REMOTE PREAMP

  To obtain a gateable, Thru-transmission signal a DM-2 in-line preamp was used to boost the received ultrasonic signal.

* SIJS Series .4 mhz undamped transducers
  57K0625P2 transmit transducer (50 OHM impedence matched)
  57K0625 receiver transducer

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5.0 TEST PROCEDURE

After intializing the equipment mentioned as listed in section 4.0, each PASGT helmet shell sample was positioned between opposing water squirters. The sample was then oriented such that the one half of the shell was as normal to the water squirters' scanning plane as possible (see figure 1). In addition, a foam tape/ lead tape strip of .250" x 1.0" was placed next to the identification mark on the inside of the helmet. This strip served as a marker (ultrasound attenuator) and can be observed on each helmet's corresponding C-Scan plot.

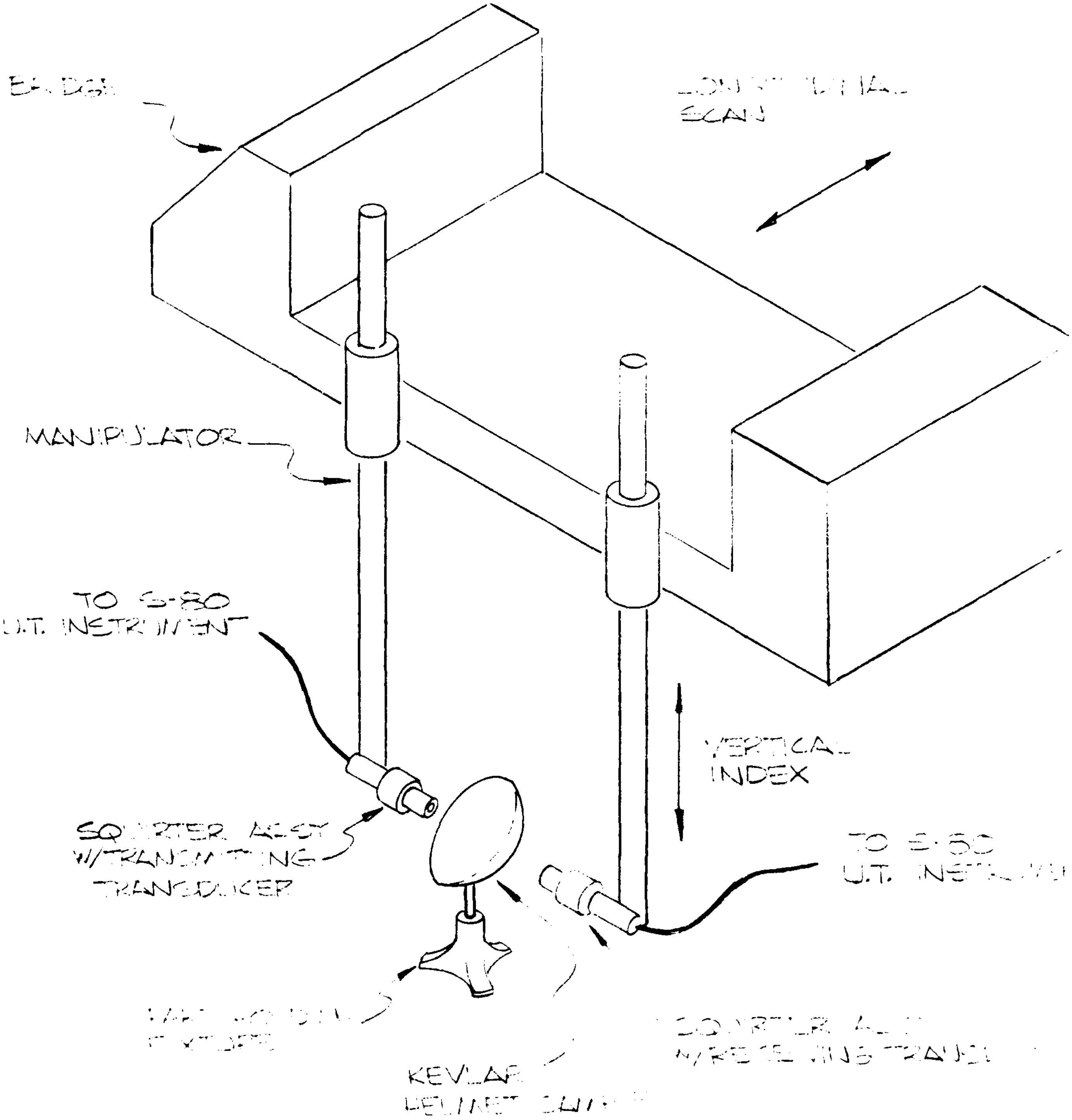
The US-542/s MIDUS (tm) scanning system was programmed to scan one half of the shell in a thru-transmission, rectilinear mode. The same scan/index window coordinates or "scan plan" was used for each subsequent sample. (2) scans were made of each shell to provide maximum coverage allowed by the part geometry. A total of (12) scans or (2) scans each of the (6) samples provided. (2) additional " Electronic Rescans " were made of each sample to enhance the presentation. A total of (24) plots are presented in section 8.0 of this report.

Using the S-80 instrument, the receiver gain level was adjusted to a sensitivity that allowed all test samples to be inspected at one setting. This was made possible by the 60 dB dynamic range logarithmic amplifier. All (6) PASGT samples could then be compared collectively for their attenuation characteristics.

To record the Ultrasonic attenuation measurements, a destination data file was created with the US-960 for each scan to be made. All pertinent identifying information was entered into the "Header block" such as the title, s/n and description.

While acquiring the Data during a scan, each .040" Sample point is compared to a grey scale Look-up table and one of (14) numerical characters is plotted. Each grey scale character represents a dB attenuation value. The darkest character (#) is the least attenuative section of the sample and the lightest character (blank) is the most attenuative. Since the 60db Dynamic Range of the pulser/receiver is directly proportional to the 0-5 VDC analog output, .083 volts is equal to 1 dB.

During a scan, all data sample points are stored in an 8 bit digitized value from 0-255 on the 40 megabyte winchester hard disk drive within the US-960. The data file which holds all the data sample points can be recalled for an "Electronic Rescan" using different grey scale look-up tables for comparative purposes with known acceptance criteria.


MANIPULATOR
TO S-80
VERTICAL
INDEX
KEVLAR

6.0 TEST RESULTS

Low frequency (.4 mhz) Ultrasonic Squirter Thru-Transmission inspection was used to inspect the PASGT helmet samples.

Since defect size resolution is partly dependent on transducer frequency, test frequencies higher than .4 mhz are desired. Additional tests showed that higher frequencies (1.0 mhz, 2.25 mhz) could not be used to examine the samples since the higher frequency transducers yielded an unacceptable signal to noise ratio. To improve this, a special high-power pulser module was used in place of the standard spike pulser within the ultrasonic instrument. This approach improved the signal to noise ratio, but not enough to justify using it for these tests.

Because such a low frequency is required to acoustically penetrate the (19) layer Kevlar samples, Conventional "Pulse-Echo" and "Reflector Plate" techniques were determined not to be feasible. The inherent material attenuation characteristics of the Kevlar helmet samples prevent using transducer frequencies above .4 mhz.

There were (2) grey scale look-up tables chosen to generate the plots in the Test Data Section of this report. Plots 1-12 used a 3 db/grey scale character look-up table and Plots 13-24 used an enhanced grey scale. The enhanced grey scale in Plots 13-24 used an (8) shade, high contrast, grey scale representing 6 db of acoustical attenuation change per character.

OBSERVATIONS:

Visually, the PASGT helmet samples exhibit wrinkles and overlapping of layers. The resin content also appears to be variable through-out the entire structure. Whether or not these conditions are permissible per specification MIL-H-44099, most all processing variables will affect the acoustical attenuation characteristics of the samples.

By examining the Plots in section 8.0, note that the Ultrasonic attenuation is most pronounced on sample number 3 and number 4. The attenuation in the crown of these (2) samples is also the most severe, although all samples exhibit high attenuation patterns in this area. It is therefore suspected that the helmet crown area is an area where the layers are not being compressed sufficiently and/or resin flow is being restricted.

The artificial defects can be seen in samples 2 thru 6 as a complete loss of sound, (blank/white) although their size varies. Since these artificial defects were created by cutting 1" squares in alternate layers, it is suspected that resin has flowed into the cut-out and created a partial bond.

In the case of sample 6 where (5) of (19) layers have been cut-out, the alignment and superimposing of the squares on top of one another also contributes to the definition of a "square" on the plots.

The overall attenuation range of the samples (30 dB) is excessive if compared with other composite materials. This is most likely due to the non-autoclaved process used to fabricate the PASGT helmets as well as the helmet geometry. Typically the greater the Ultrasonic attenuation range, the greater the porosity content of the structure.

7.0 CONCLUSIONS

Low Frequency Ultrasonic inspection, using the Squirter Thru-Transmission technique, can be applied to the inspection of the PASGT helmets. Although, because of the high acoustical attenuation characteristics of the samples, .4 mhz frequency transducers were required. This is the lowest standard transducer frequency used in ultrasonic inspection and the least sensitive in terms of defect resolution.

Developing an ultrasonic test technique capable of determining an acoustical attenuation difference between an area of 15 plys versus 16 plys of Kevlar does not appear to be feasible. This is due to the overall acoustical attenuation inconsistencies exhibited within this structure. The use of Real-Time Radiography inspection as described in the technical report (TR-86-2) would be a more feasible approach to detecting differences in ply number and orientation.

Additional work will need to be undertaken to assist in development of acceptable ultrasonic reference standards.

RECOMMENDATIONS

Further ultrasonic evaluations should be carried out to qualify using the .4 mhz, Thru-transmission inspection method for production inspection of the PASGT helmets. Reference standards with artificial defects of various known sizes and types must be examined to determine the minimum size defect that can be detected within a (19) layer kevlar structure.

Additional effort in equipment development is required. A study of through-put rate versus system configuration is required to provide design direction that can meet production inspection rate requirements.

A rapid, cost effective method would be to develop a go/no-go ultrasonic test using (2) opposing multi-element transducer arrays that conform to the inside and outside geometry of the helmet. This approach would not require complex contour following of the transducers to the helmet geometry.

Each helmet could be immersed between the transducer arrays and the ultrasonic attenuation measurements compared to a computerized data base. Deposition of the helmets' integrity would then be logged and printed out for the operator. The number of elements or transducers required within an array would be dependent upon the minimum size defect to be detected.

8.0 TEST DATA

* PASGT HELMET SHELL SAMPLES
(19) LAYERS OF ARAMID (KEVLAR)

NOTE: ALL SAMPLES (EXCEPT # 1) HAD ARTIFICIAL DEFECTS FABRICATED INTO THE CENTER OF THE CROWN (TOP) OF THE SHELL SAMPLE. THESE DEFECTS WERE CREATED BY CUTTING A 1.0" SQUARE FROM THE LAYER(S) PRIOR TO BONDING. EACH OF THE (19) LAYERS ARE IDENTIFIED AS 1 THROUGH 19 WITH LAYER 1 ON THE INSIDE (DATE CODE SIDE) OF THE SAMPLE. IN ADDITION TO THE MANUFACTURED DEFECTS A .250" x 1.0" FOAM TAPE STRIP WAS AFFIXED TO THE INSIDE OF THE HELMET NEXT TO THE CODE FOR PLOT ORIENTATION PURPOSES.

SAMPLE NO.	DEFECT PLACEMENT LAYER(S)	ATTENUATION RANGE
1	NONE	
2	3	
3	3,5	
4	3,5,7	
5	3,5,7,9	
6	5,7,9,11,13	

Each Scan (Data File) made of a PASGT Helmet sample had the following header information associated with it. This is an example of the typical operator inputs made prior to scanning.

POST SCAN PLOT

[illegible]

In order to ease the interpretation and identification of the plots, the following data reduction form is presented instead of individual header information for each plot.

DATA REDUCTION FORM

The following tabulation is given for plot identification and comparison:

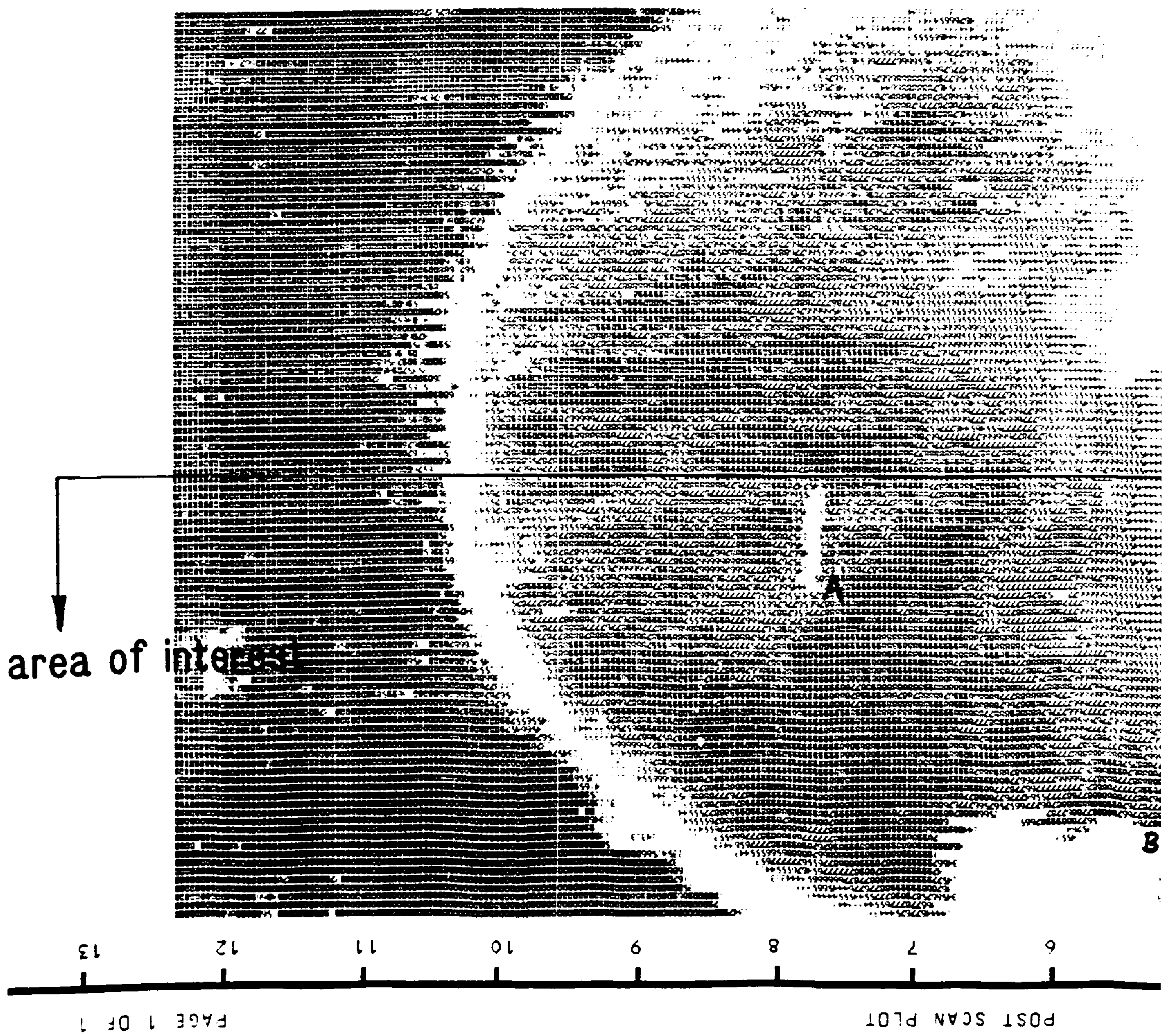
PLOT NO.	Db/GREY SCALE CHARACTER	AREA OF INTEREST
1a	3	RIGHT HALF
1b	3	LEFT HALF
1c	6	RIGHT HALF
1d	6	LEFT HALF
2a	3	RIGHT HALF
2b	3	LEFT HALF
2c	6	RIGHT HALF
2d	6	LEFT HALF
3a	3	RIGHT HALF
3b	3	LEFT HALF
3c	6	RIGHT HALF
3d	6	LEFT HALF
4a	3	RIGHT HALF
4b	3	LEFT HALF
4c	6	RIGHT HALF
4d	6	LEFT HALF
5a	3	RIGHT HALF
5b	3	LEFT HALF
5c	6	RIGHT HALF
5d	6	LEFT HALF
6a	3	RIGHT HALF
6b	3	LEFT HALF
6c	6	RIGHT HALF
6d	6	LEFT HALF

The following letters designate the typical ultrasonic indications found on each plot:

A : .250" x 1.0" Foam tape strip
B : Tooling (clamping fixture)
C : 1.0" x 1.0" Artificial Defect

1-A

SAMPLE NO. 1



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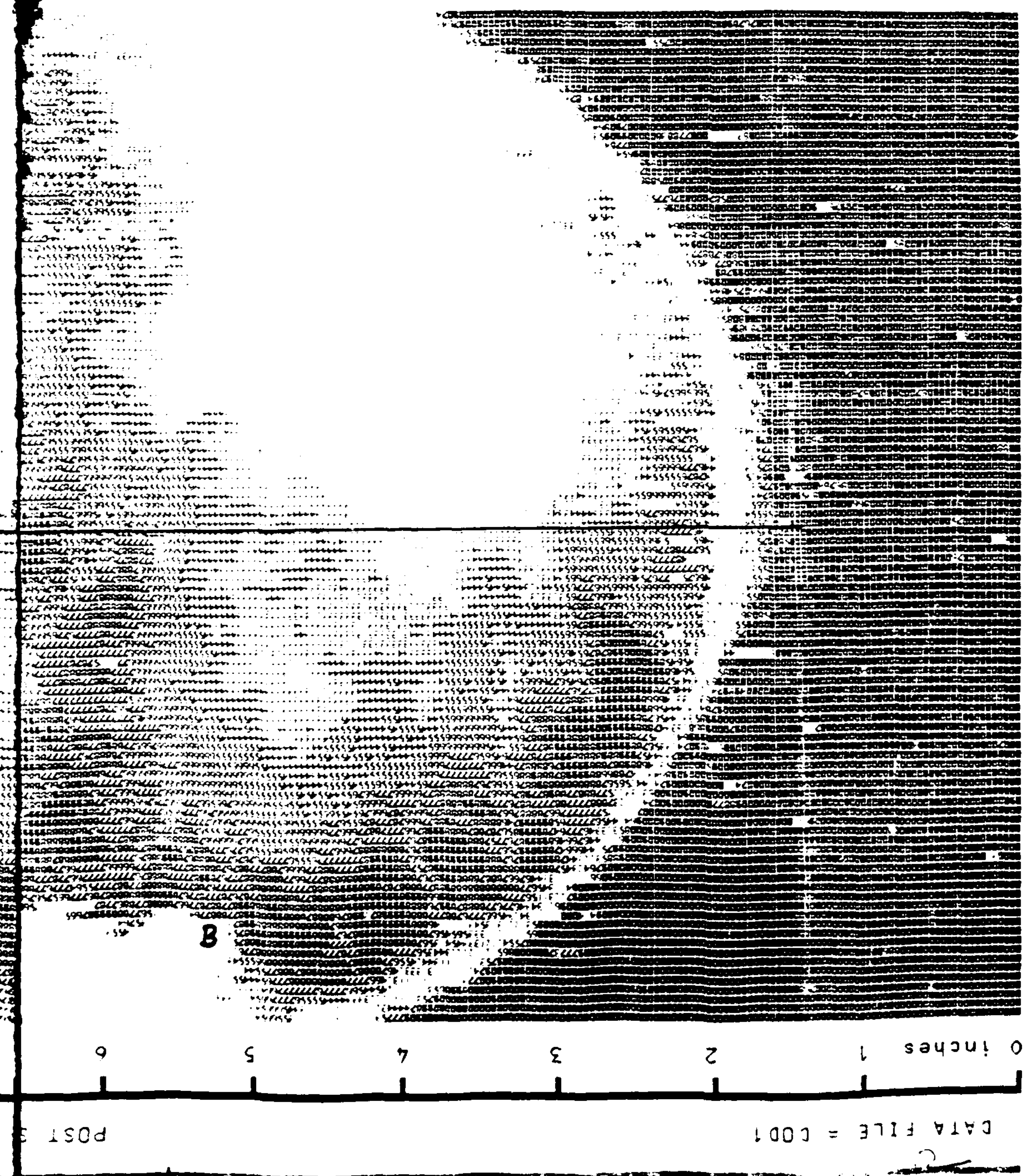
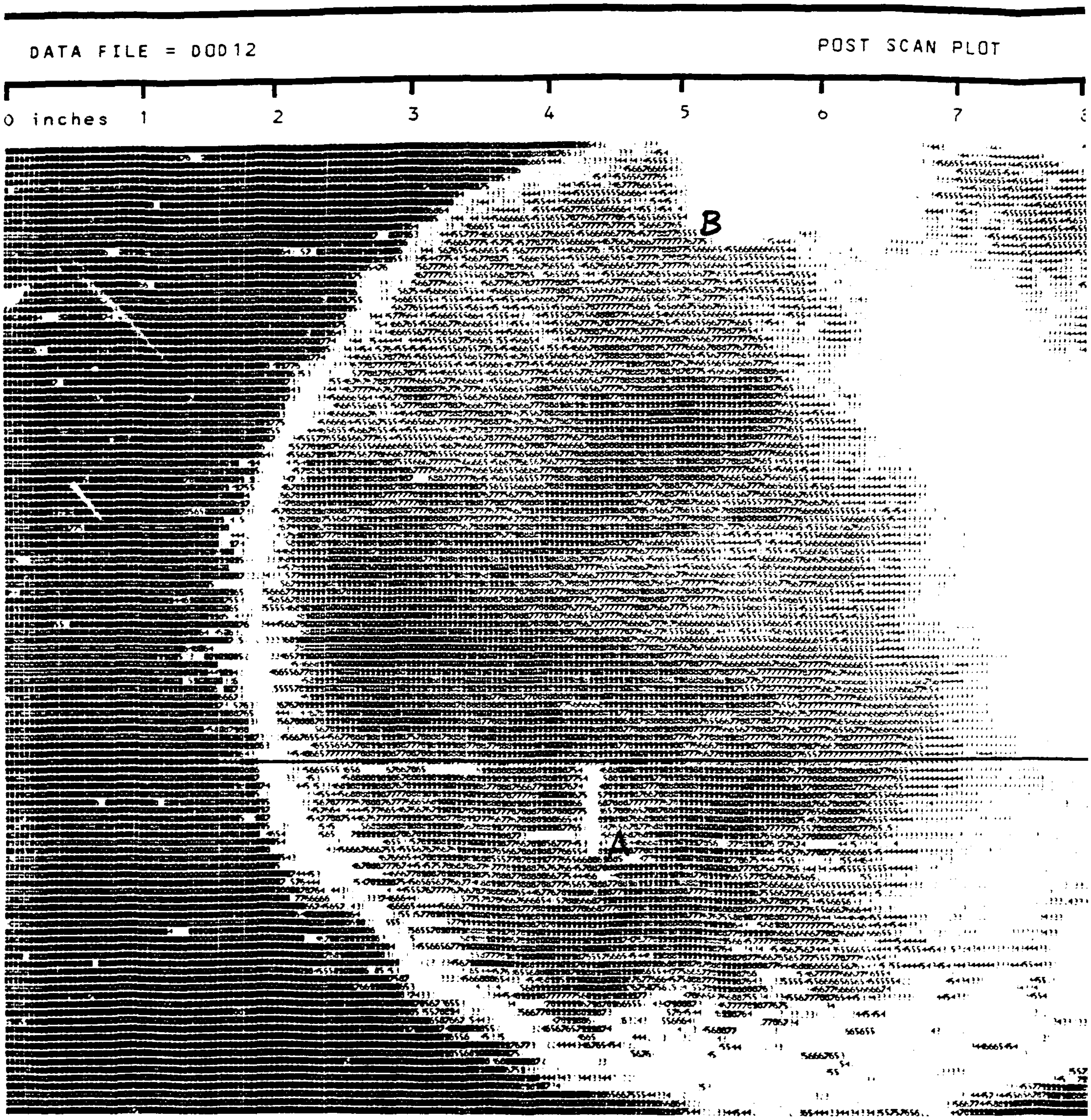
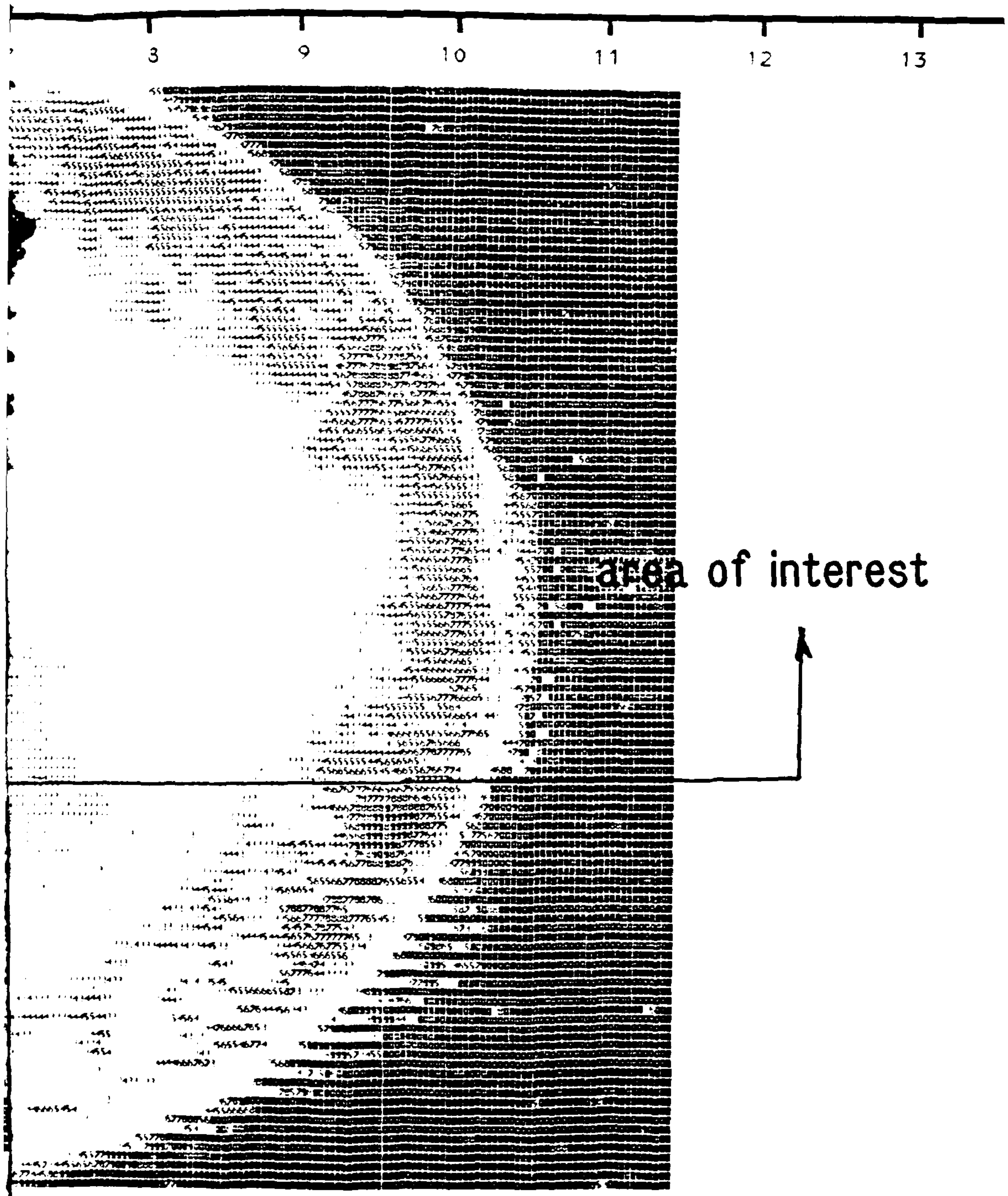




SAMPLE NO. 1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area of interest

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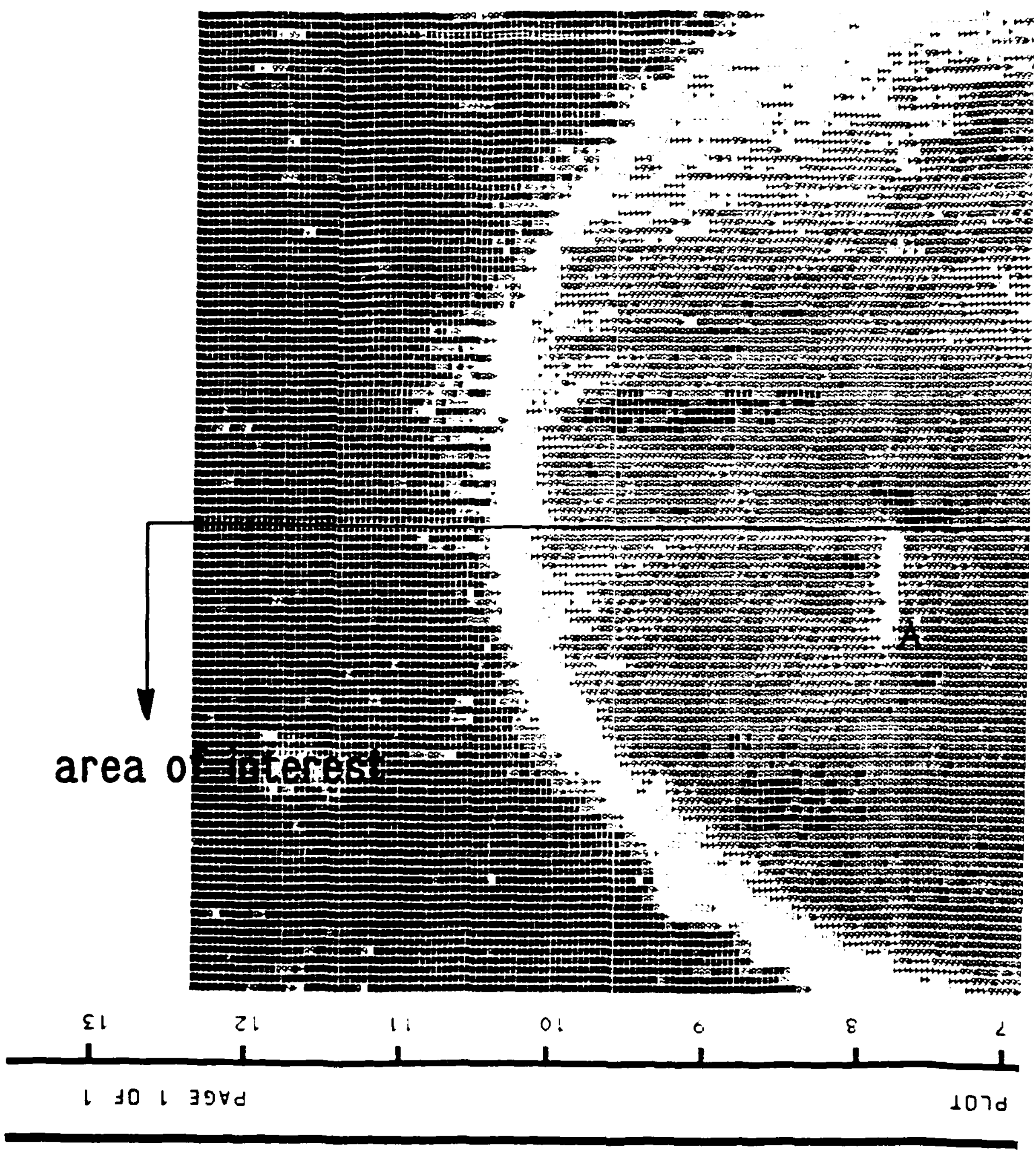

1-C

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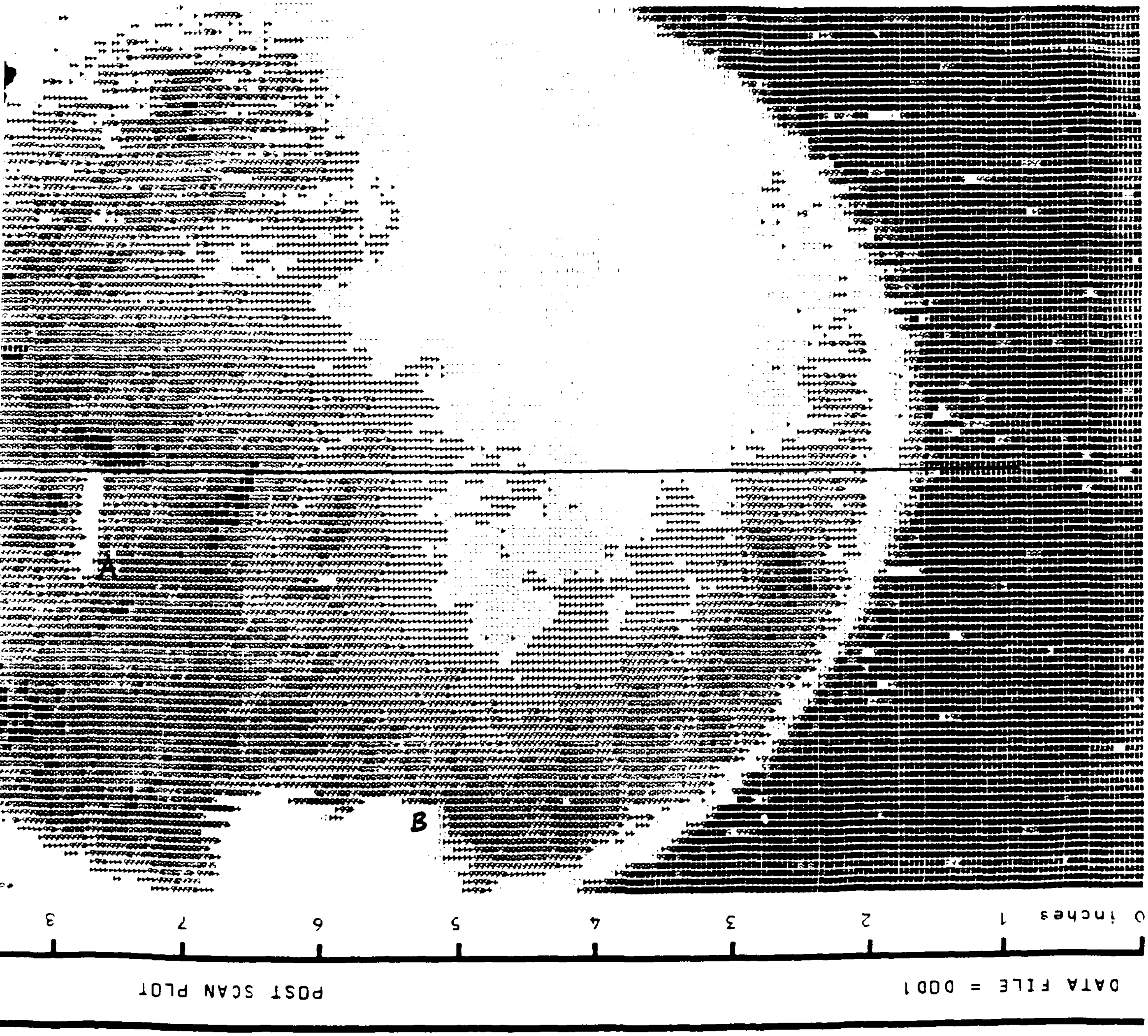

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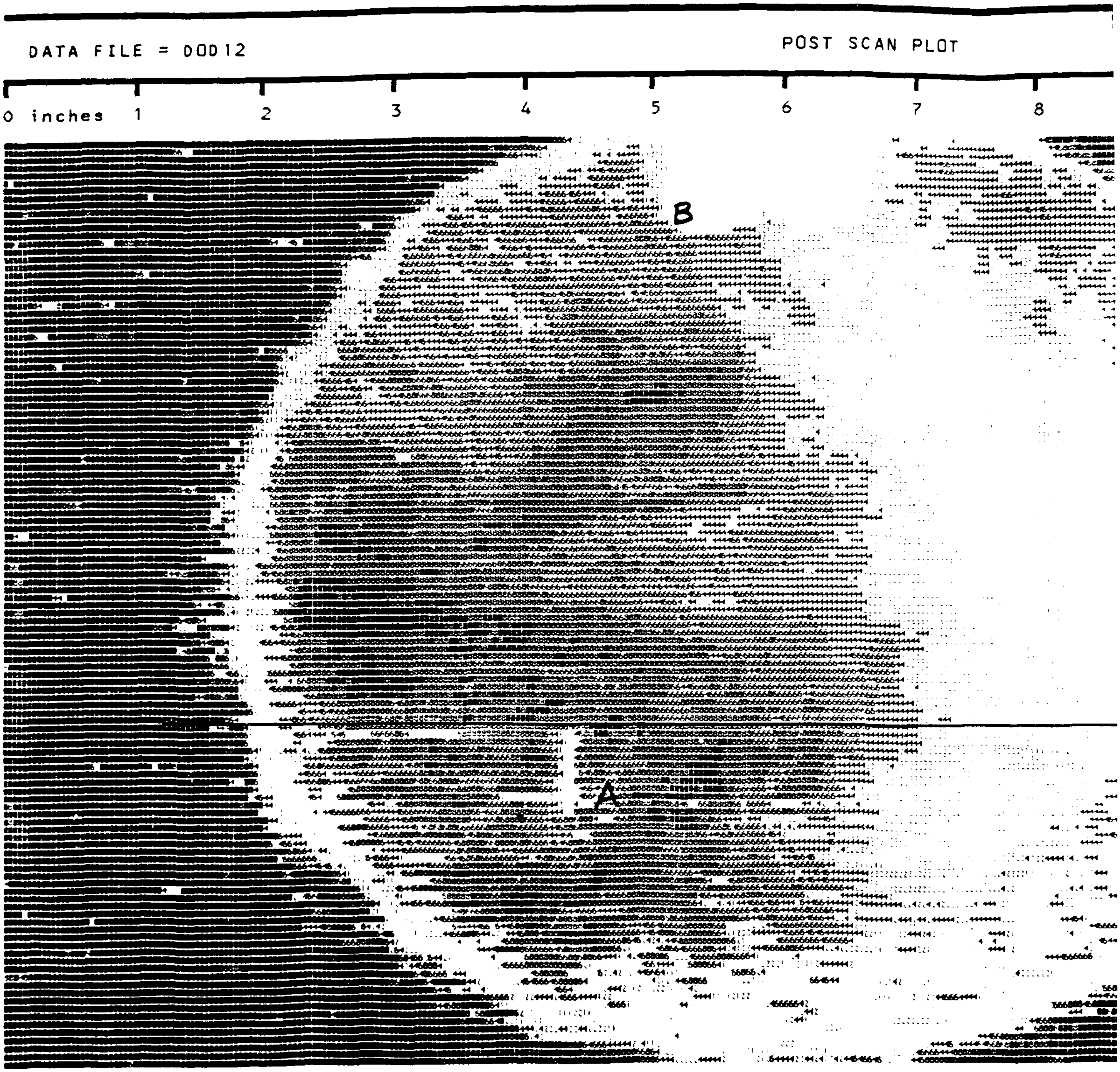

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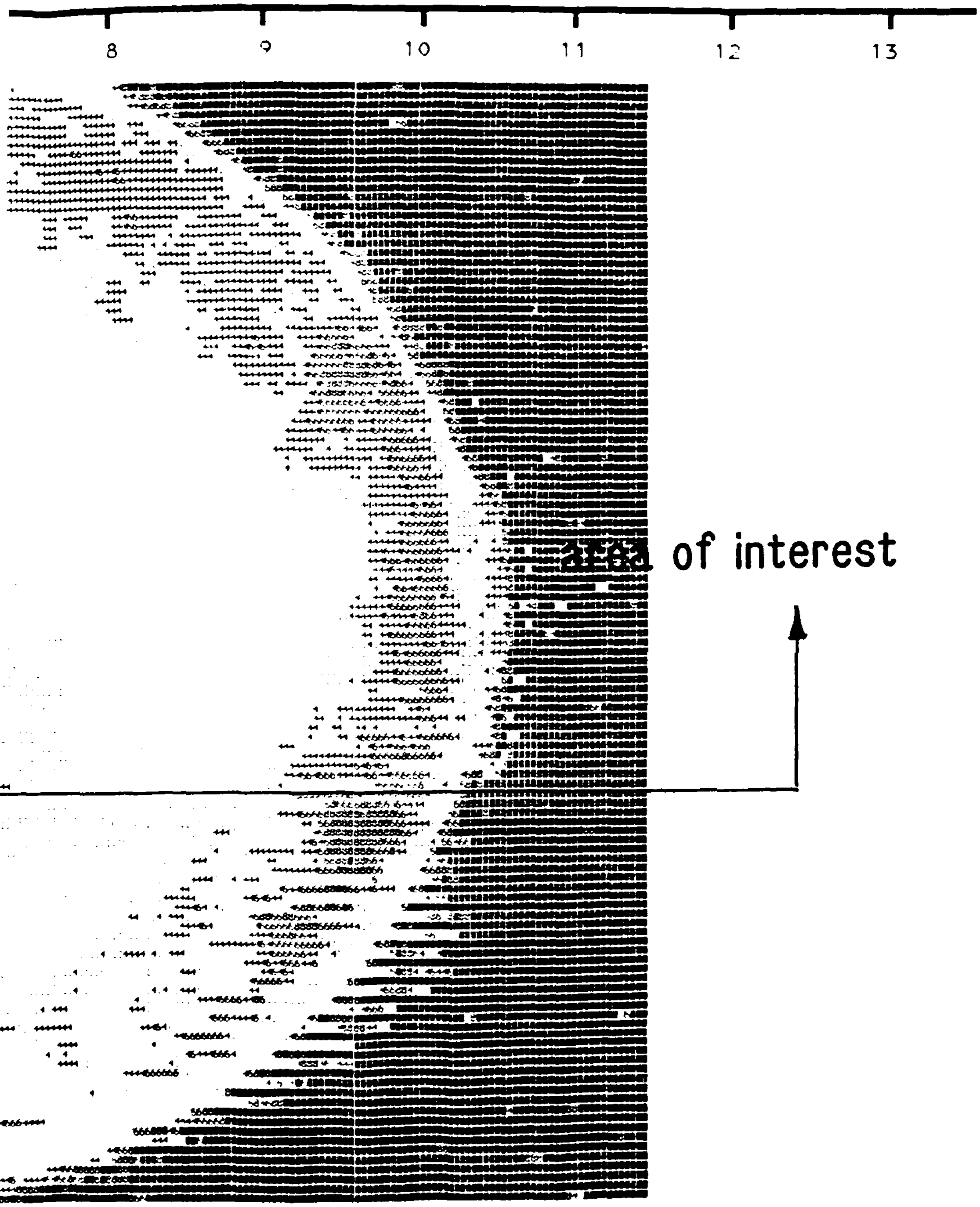
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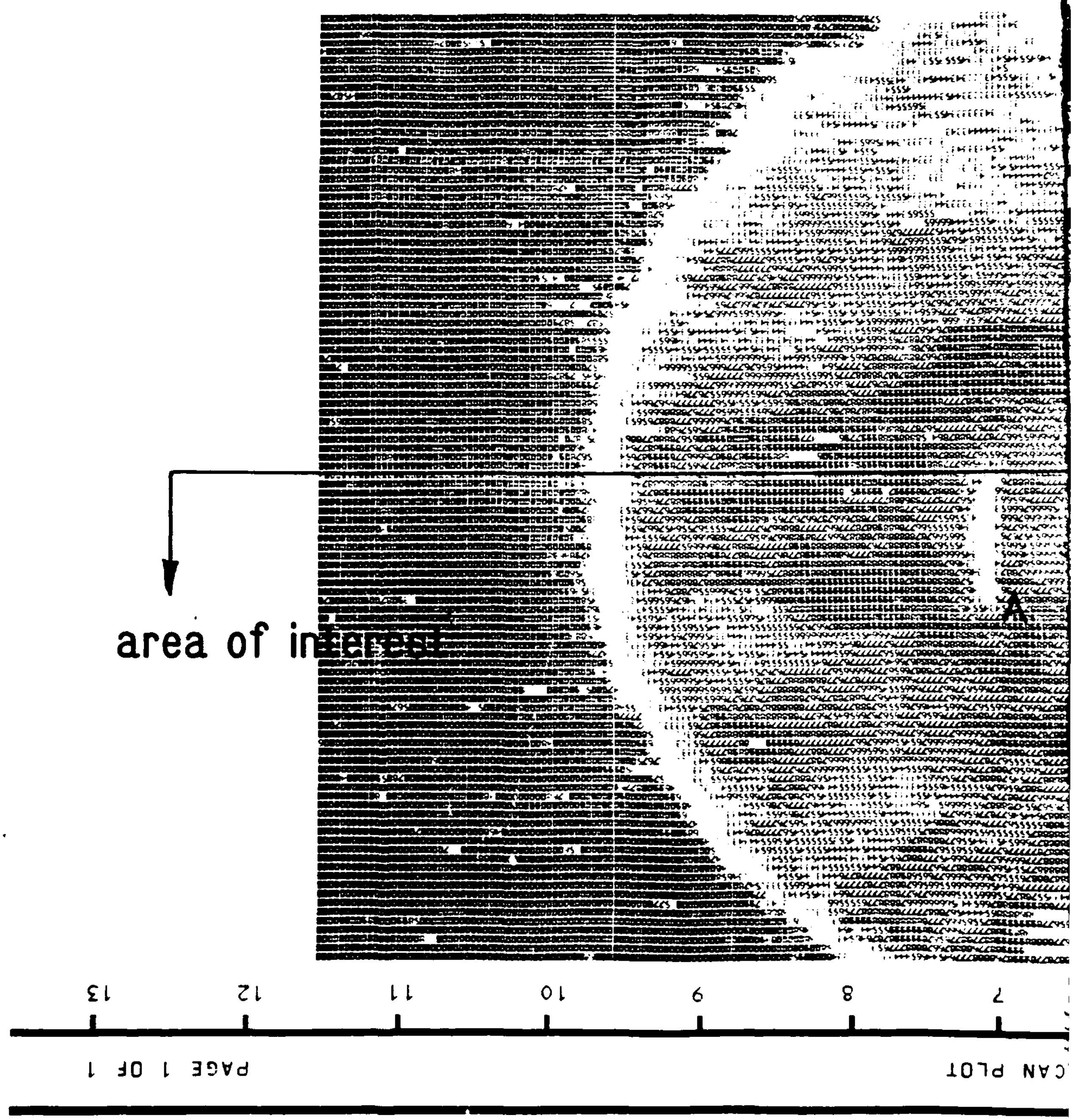

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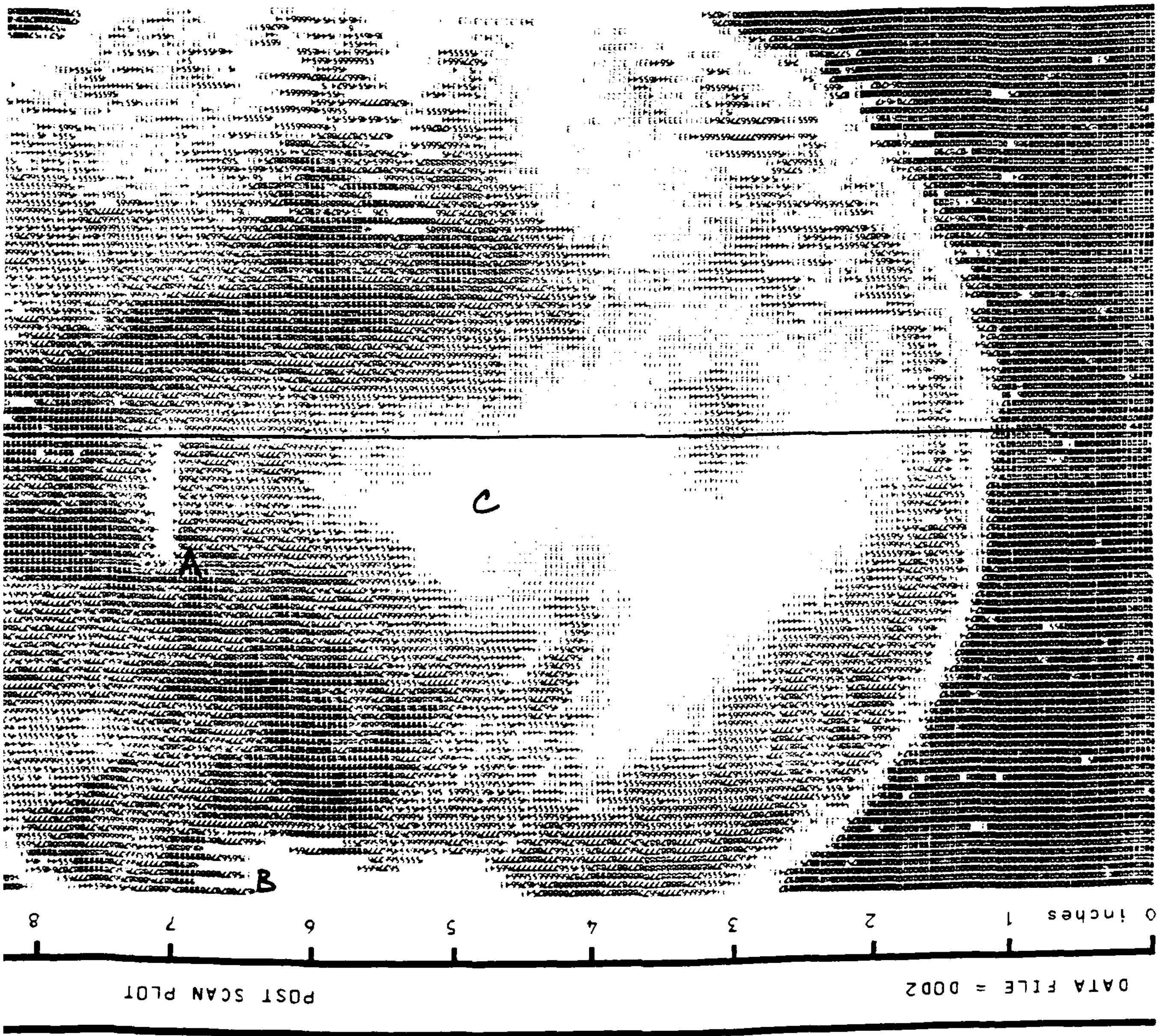

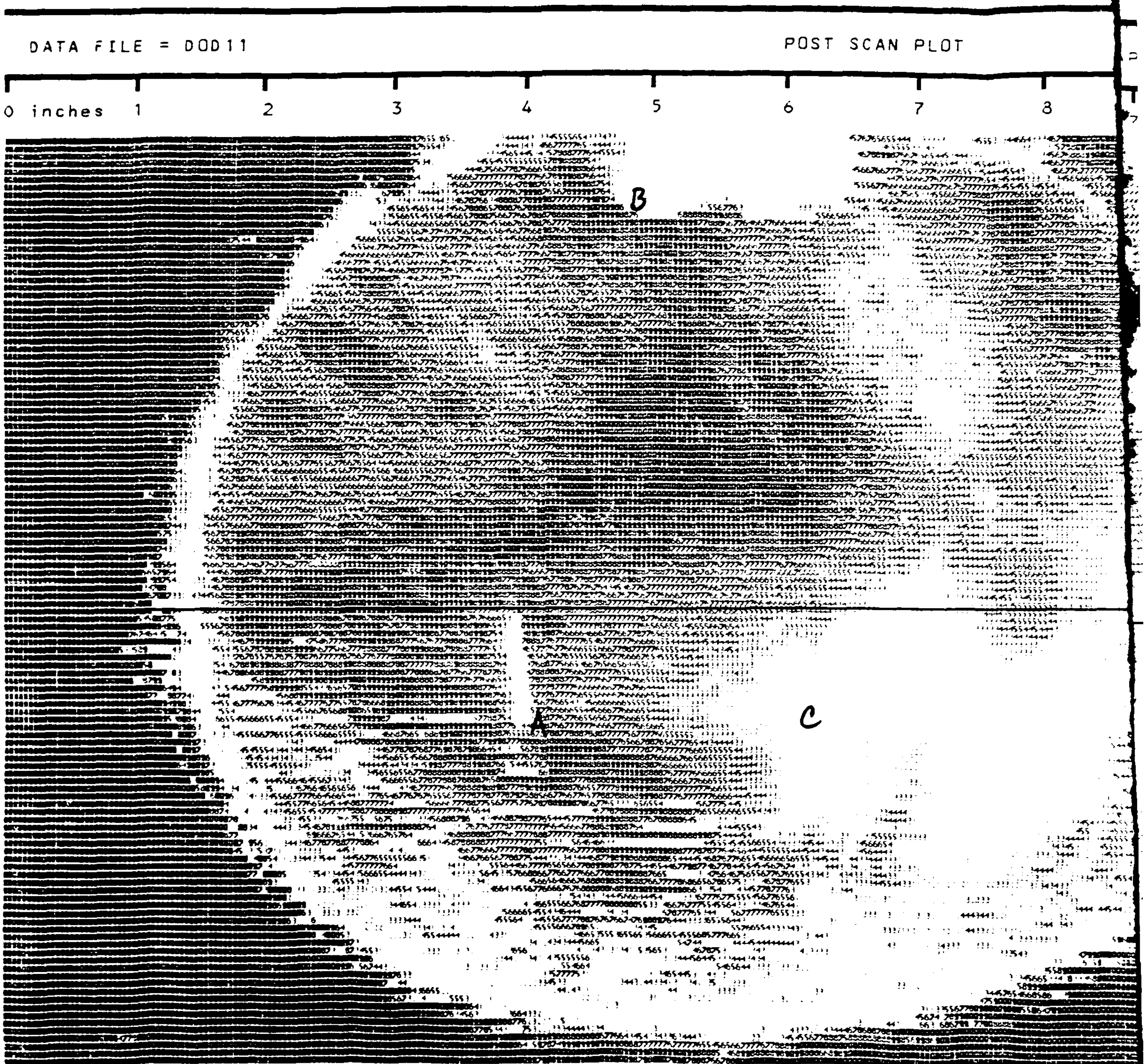

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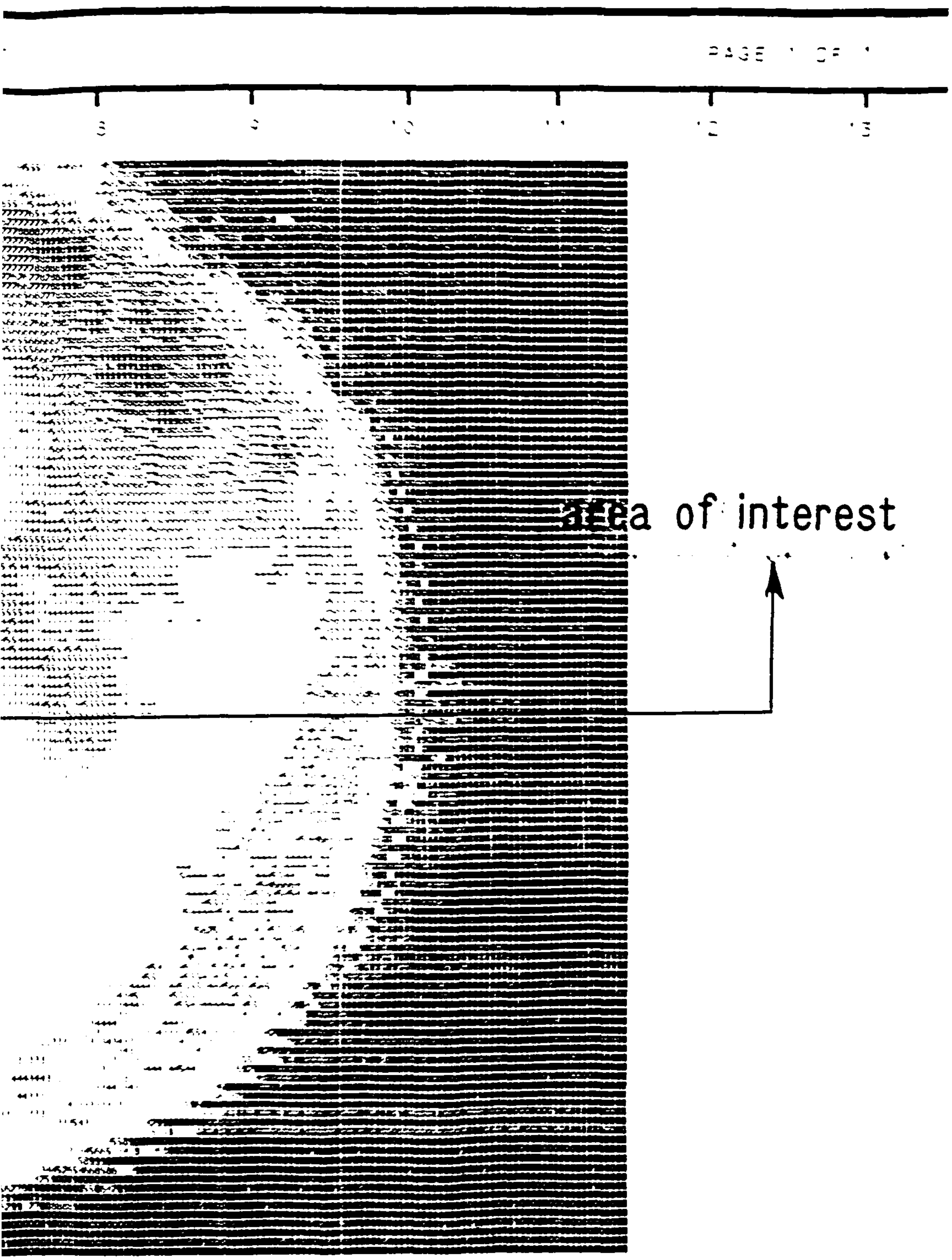
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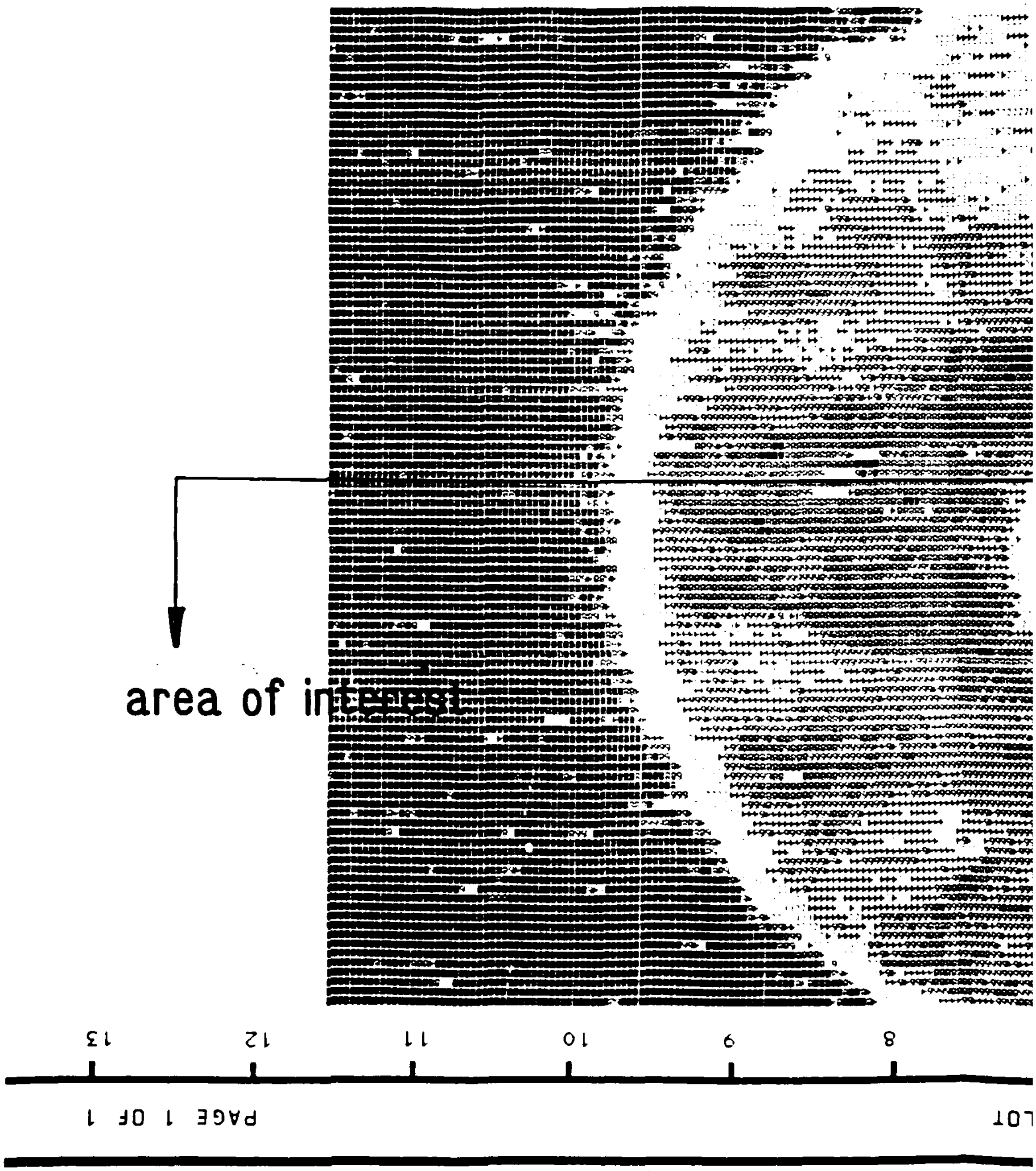
area of interest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PAGE 1 OF 1

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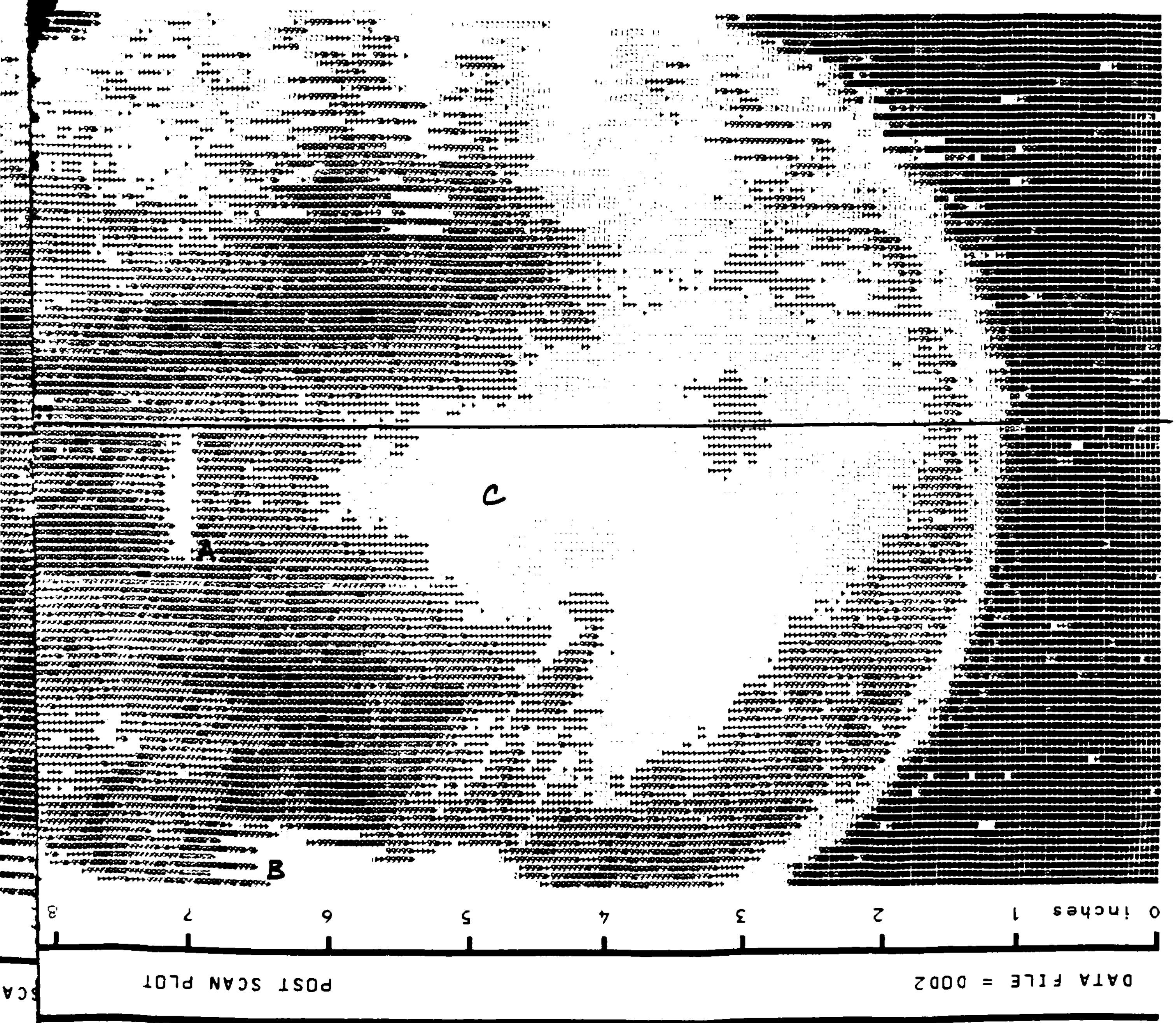

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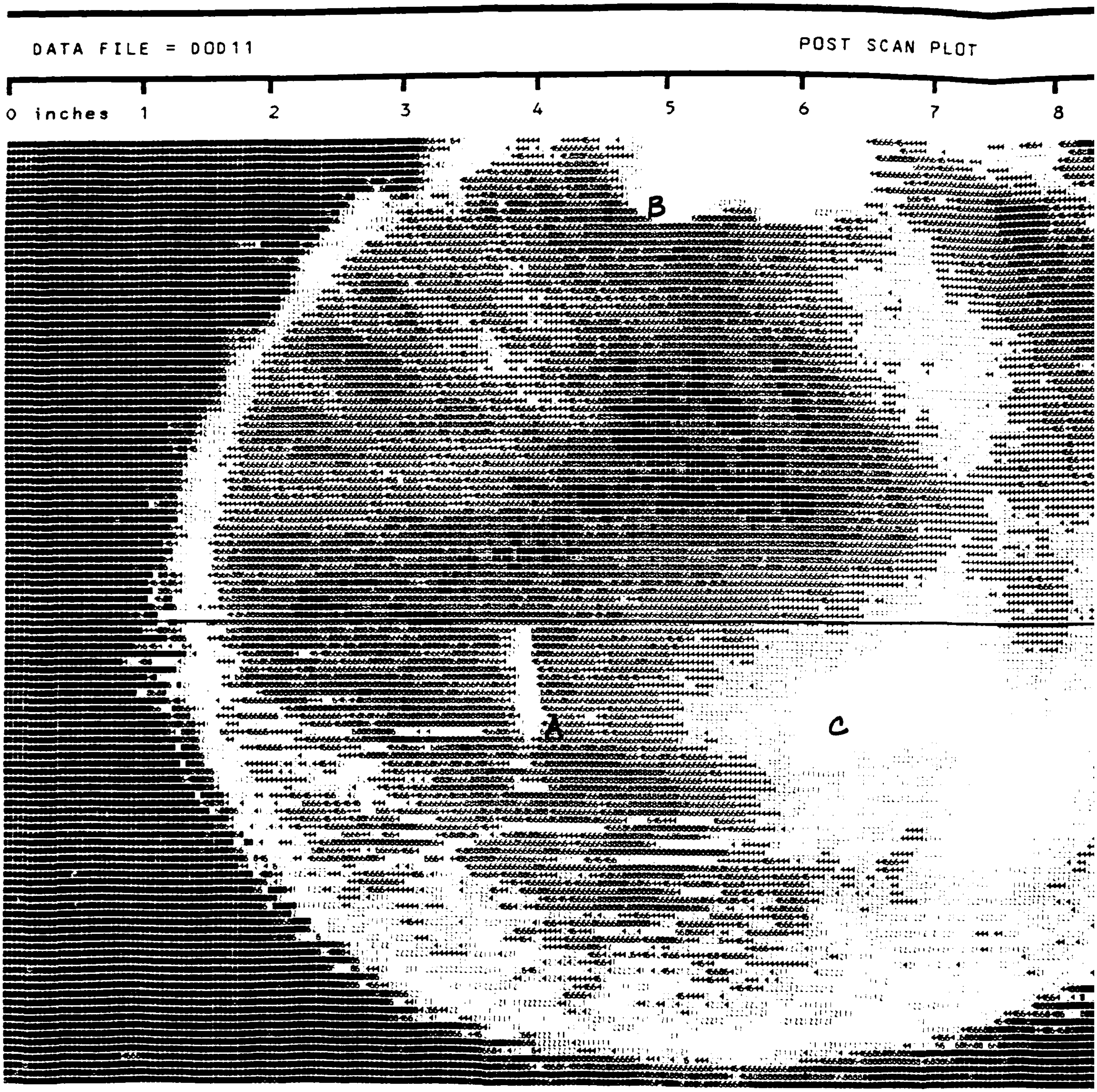

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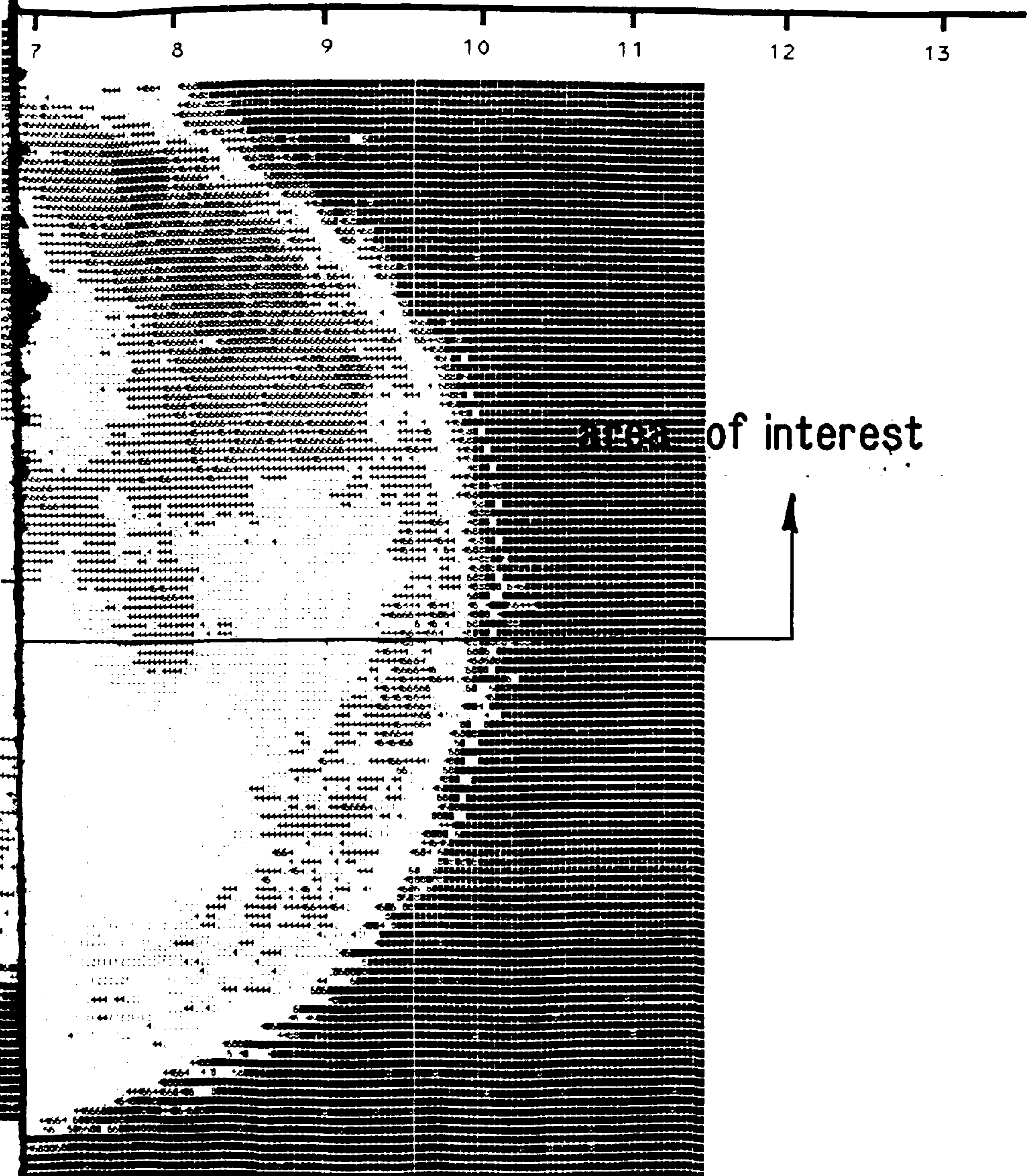
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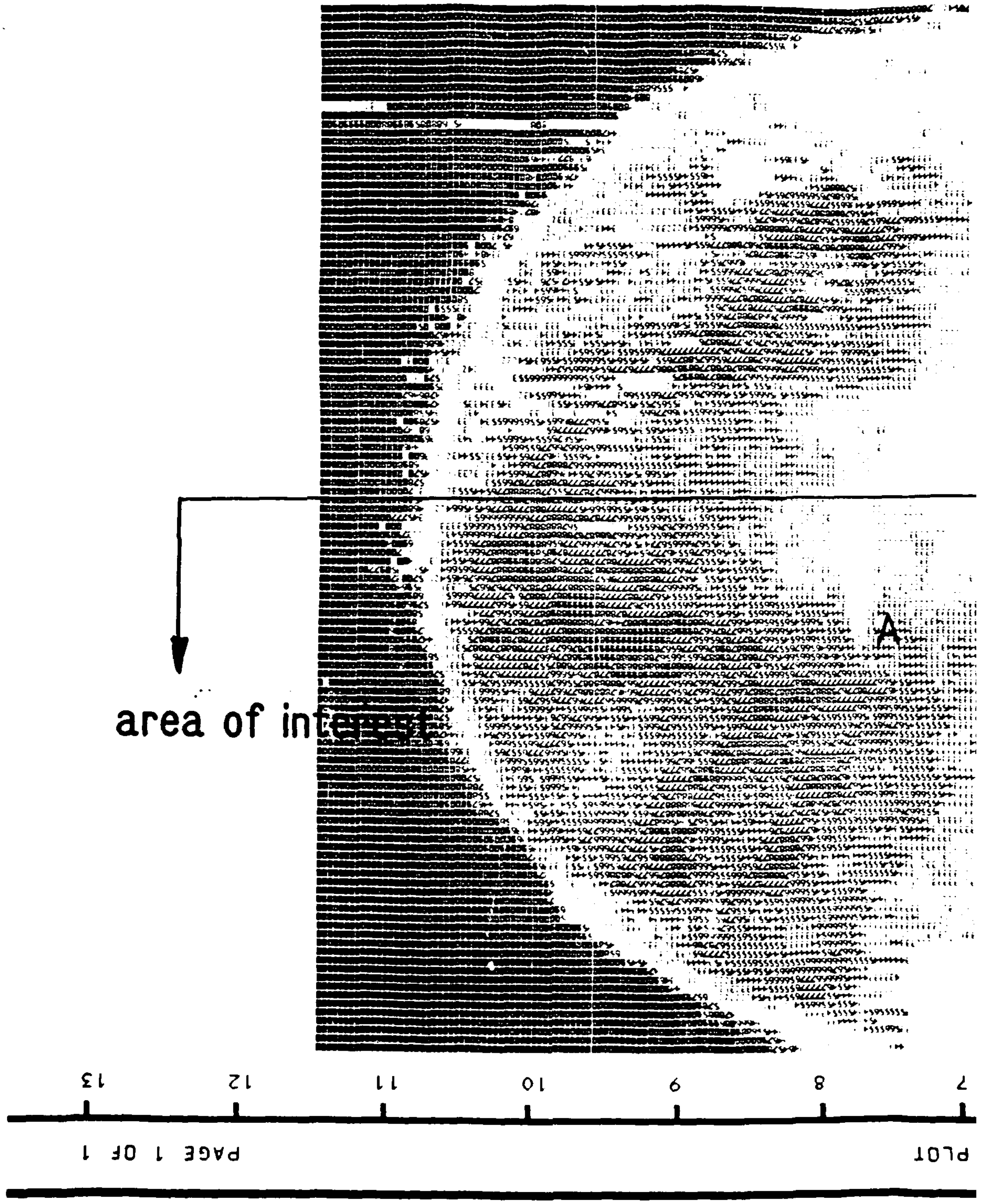

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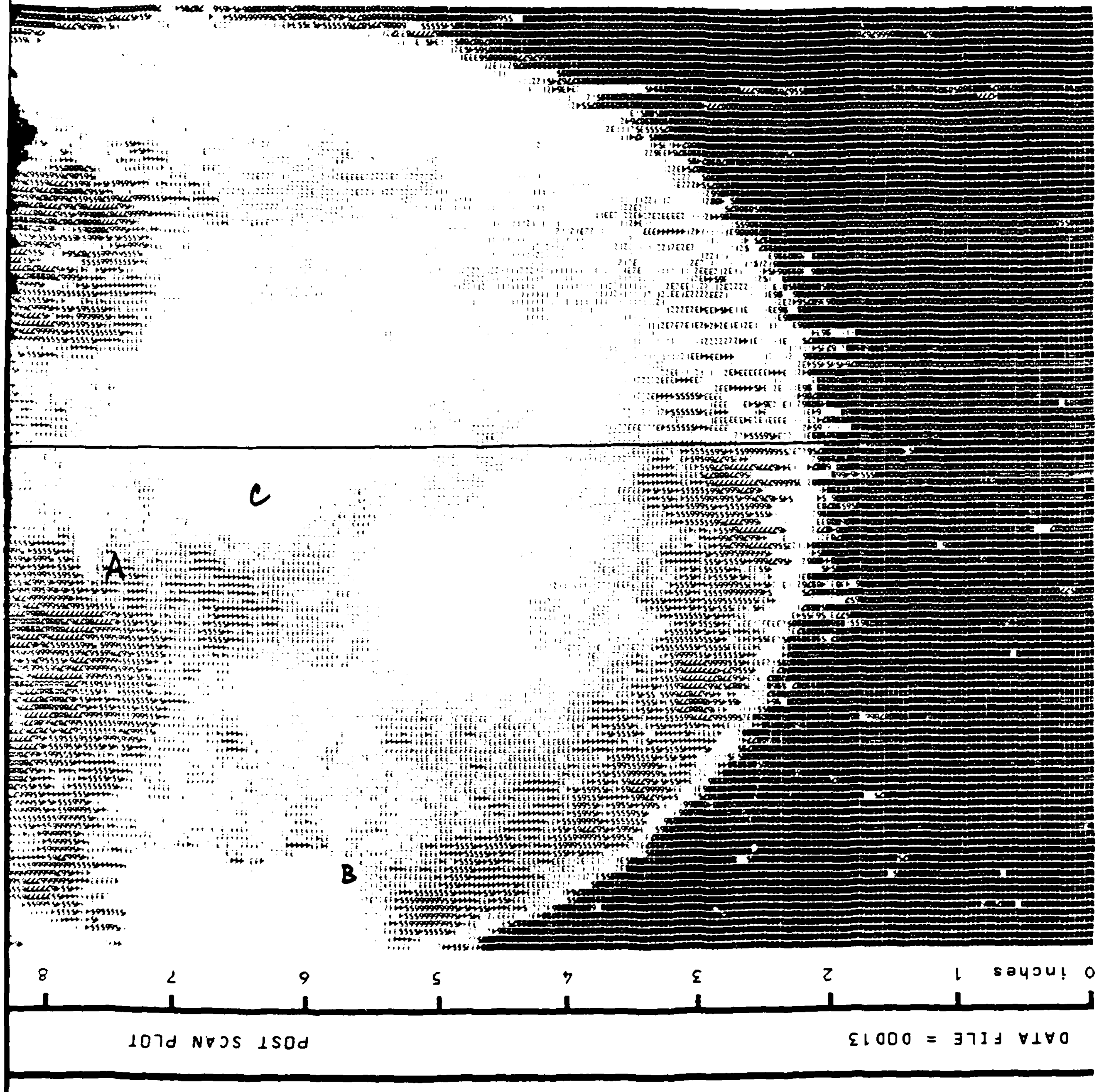

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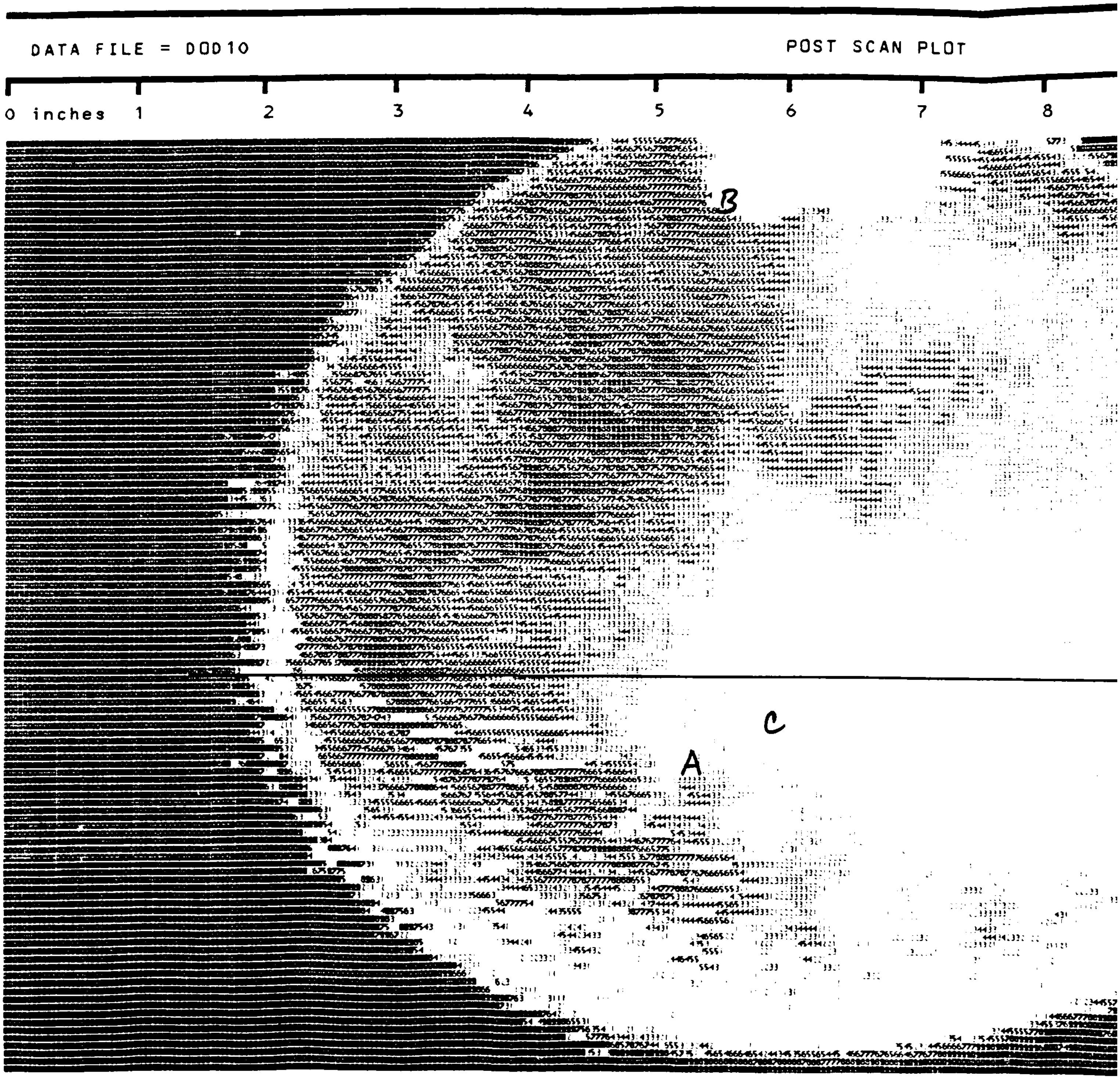

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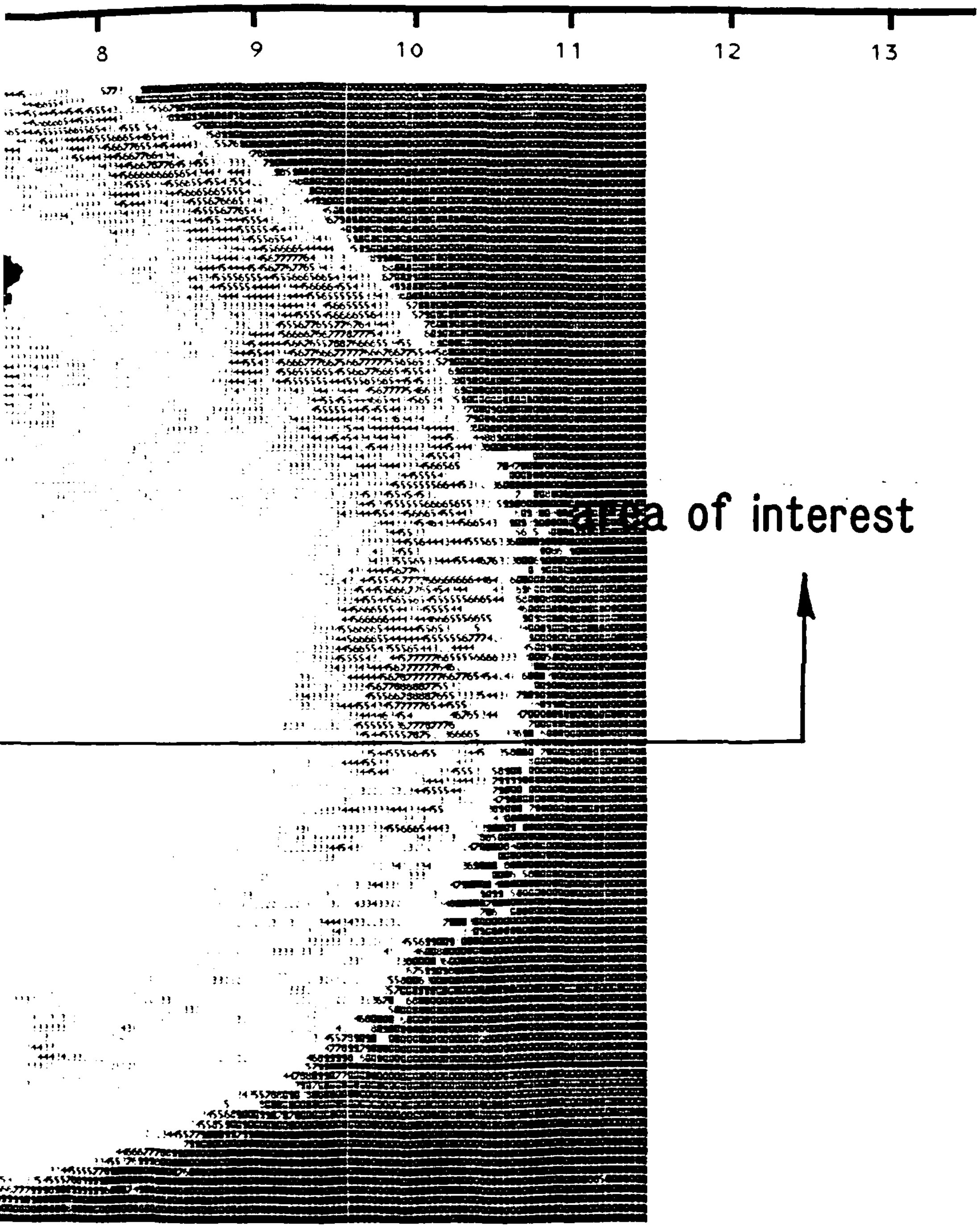

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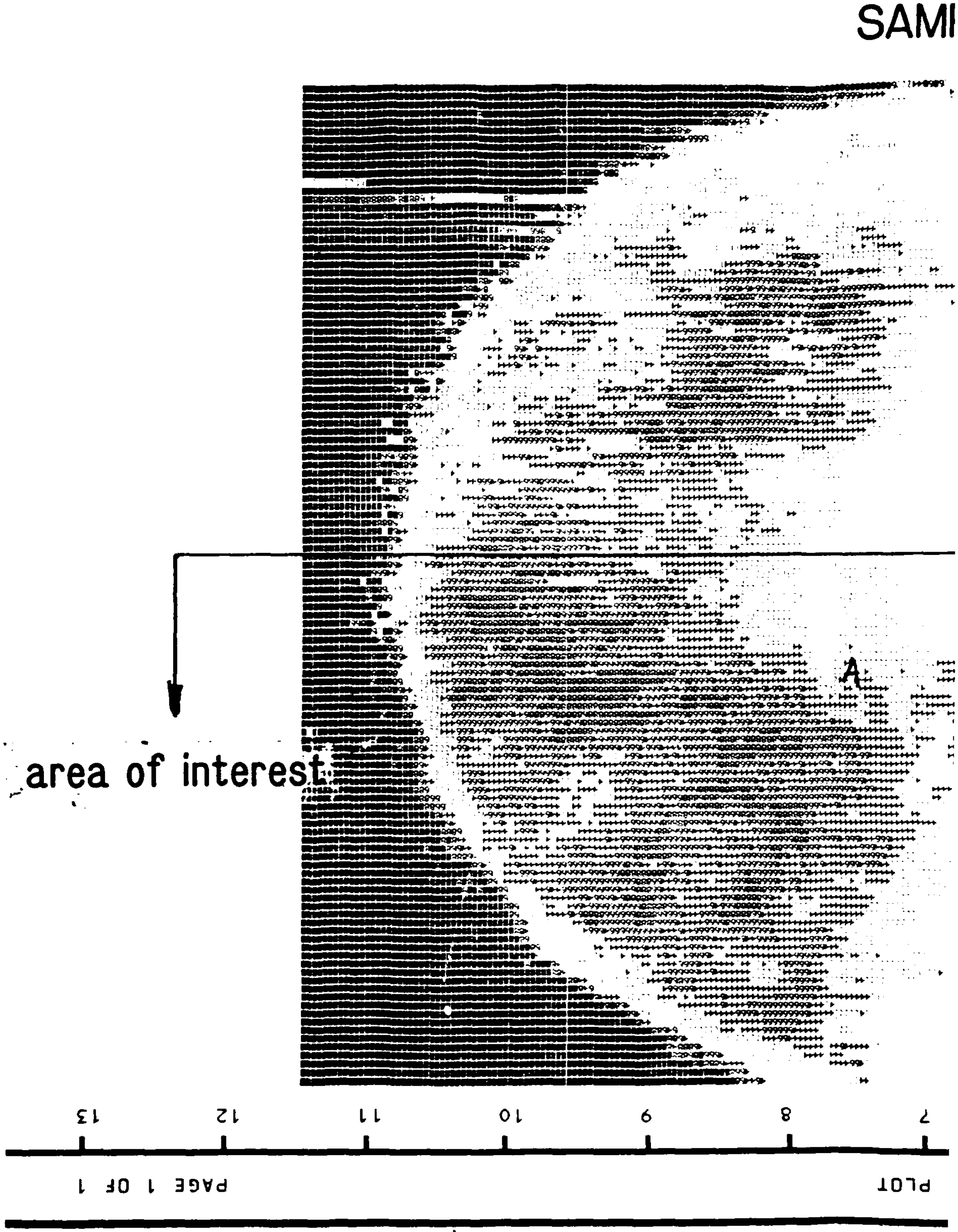
area of interest
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PAGE 1 OF 1
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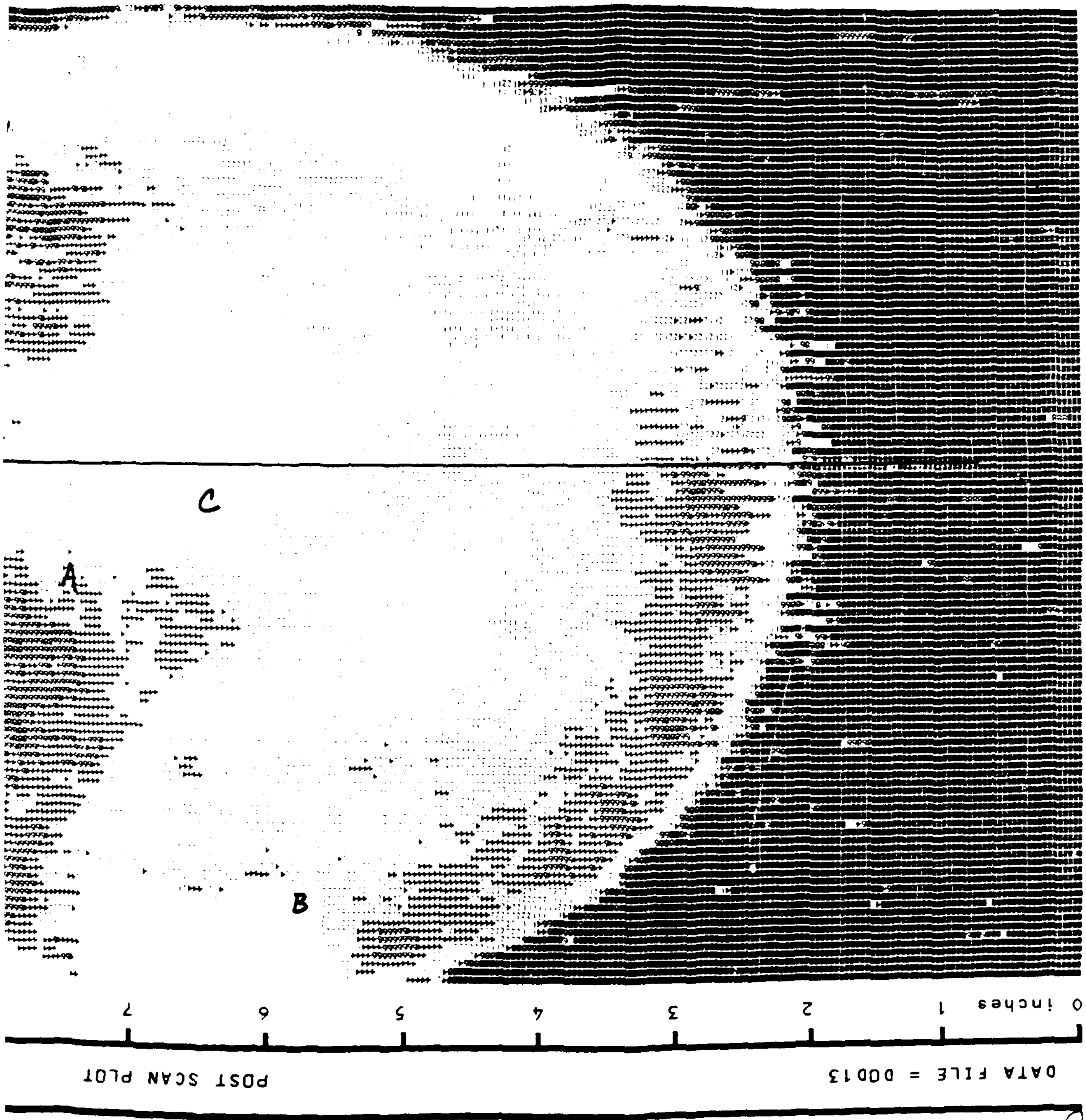

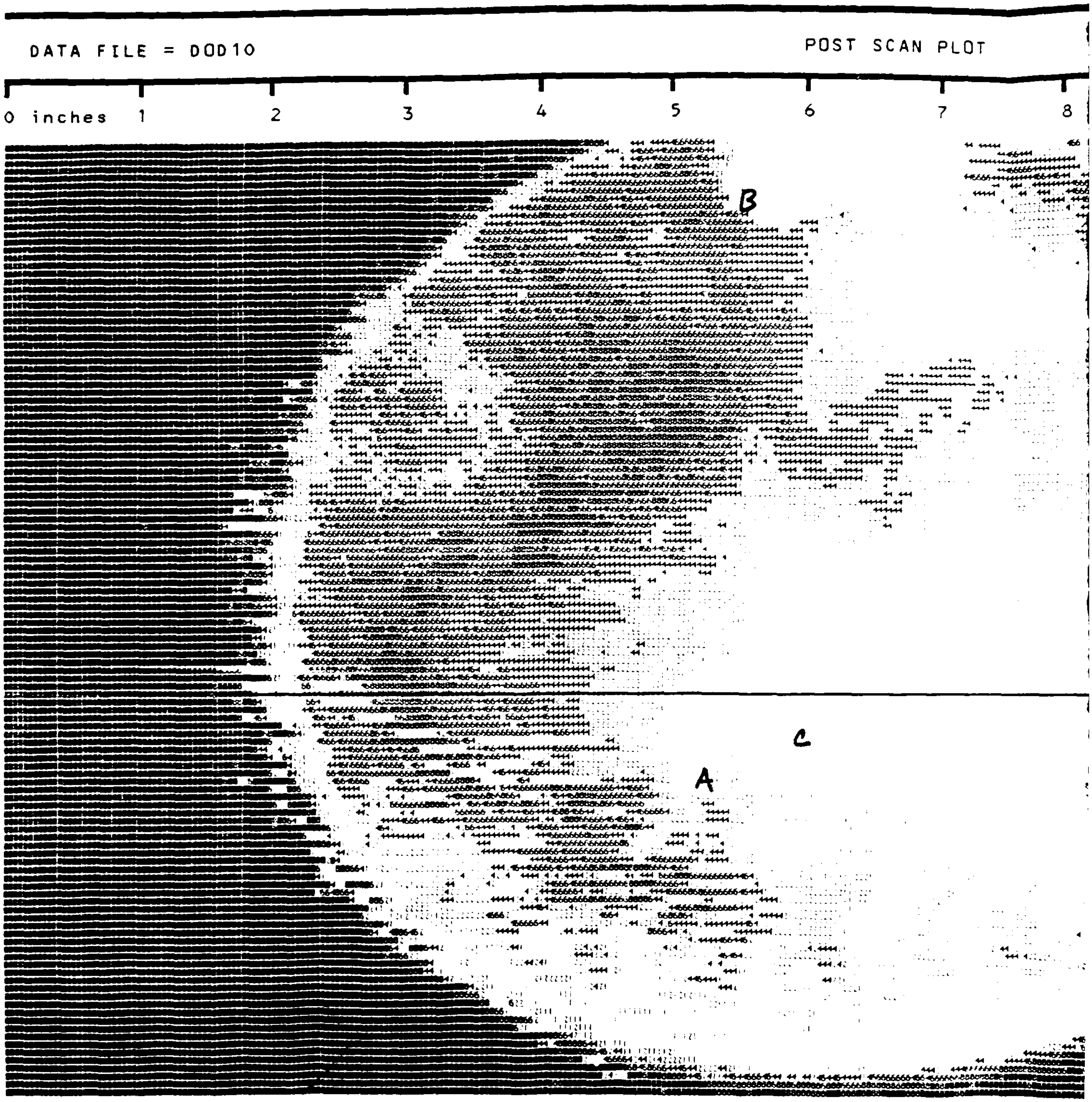

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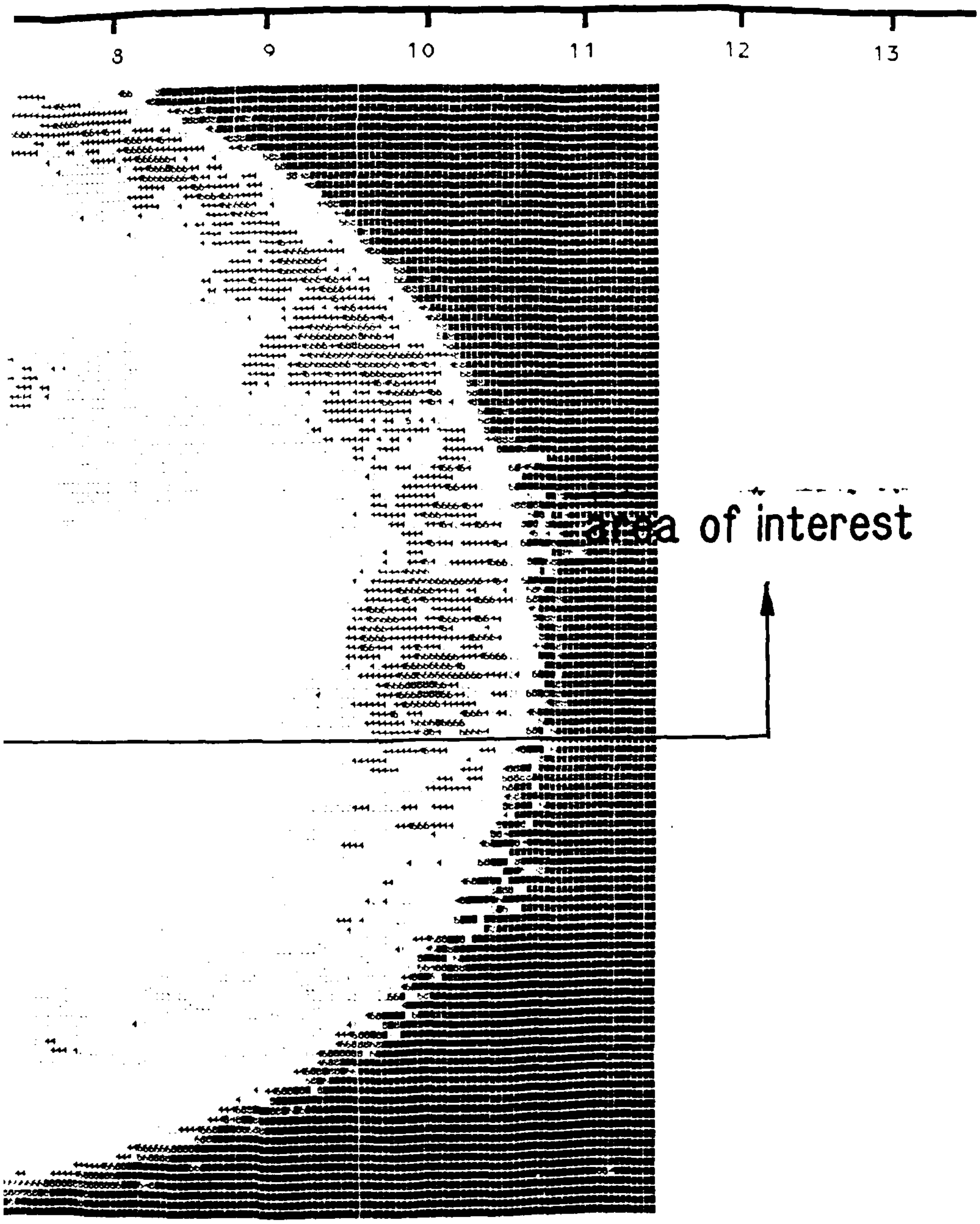

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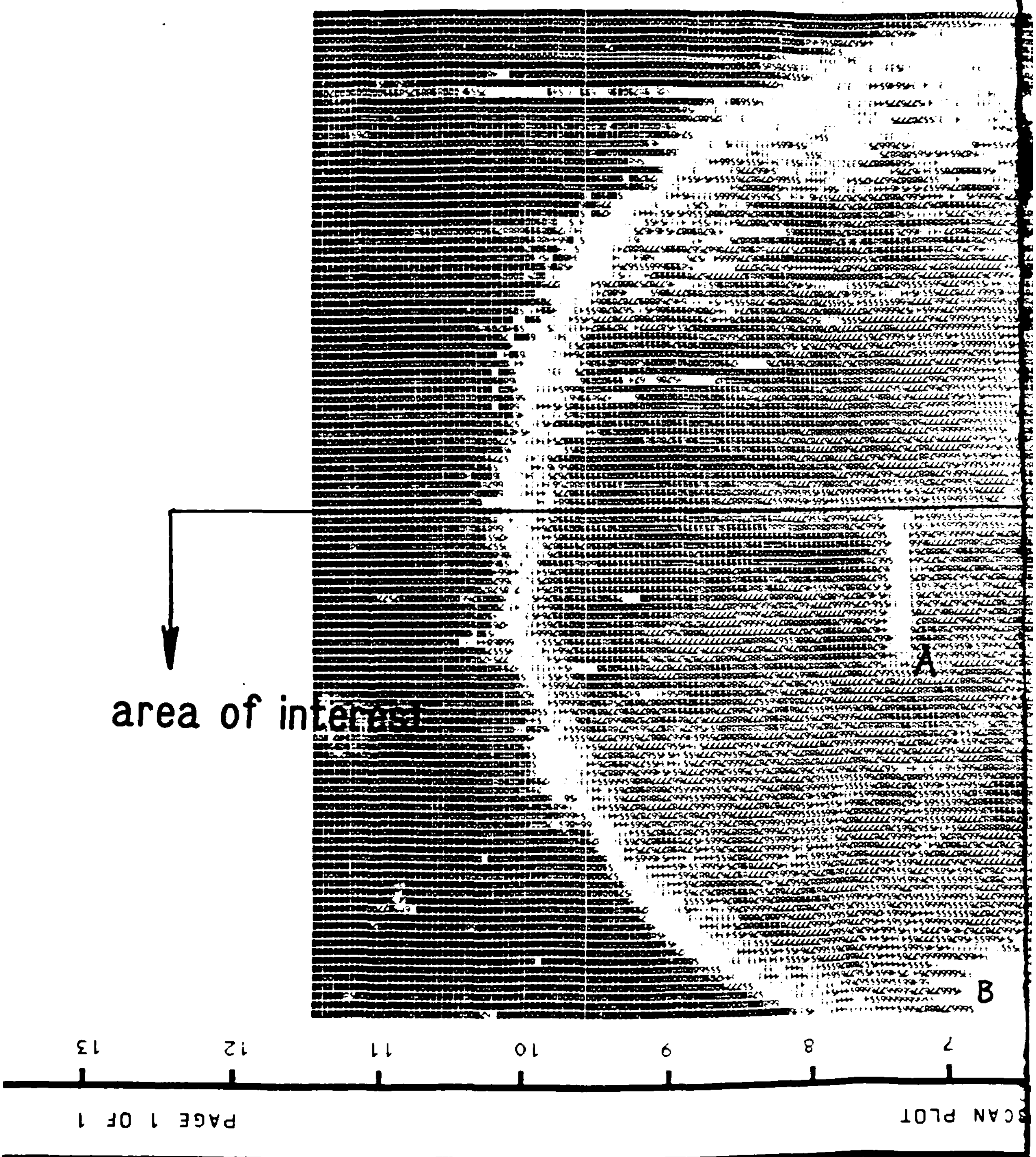

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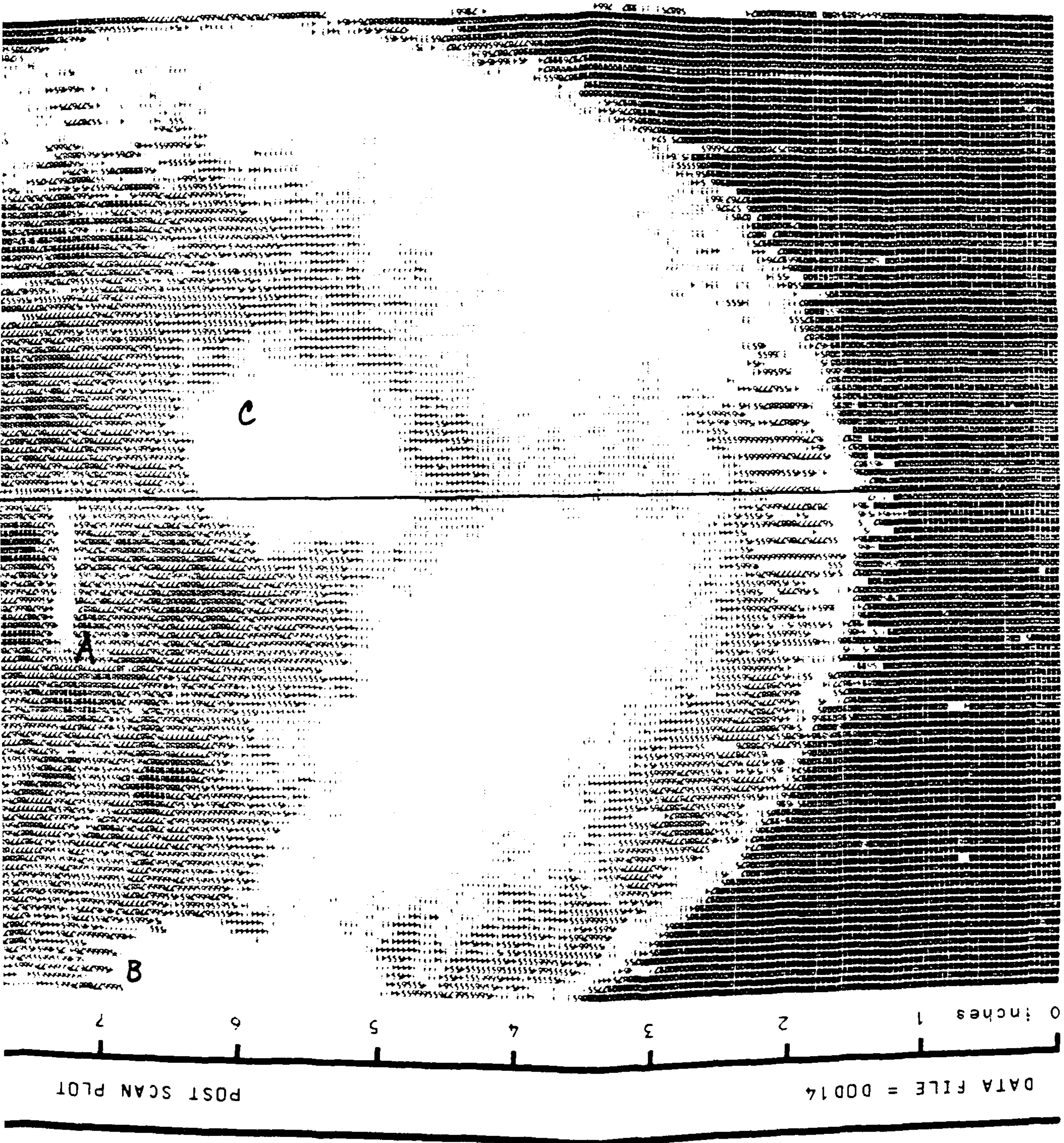

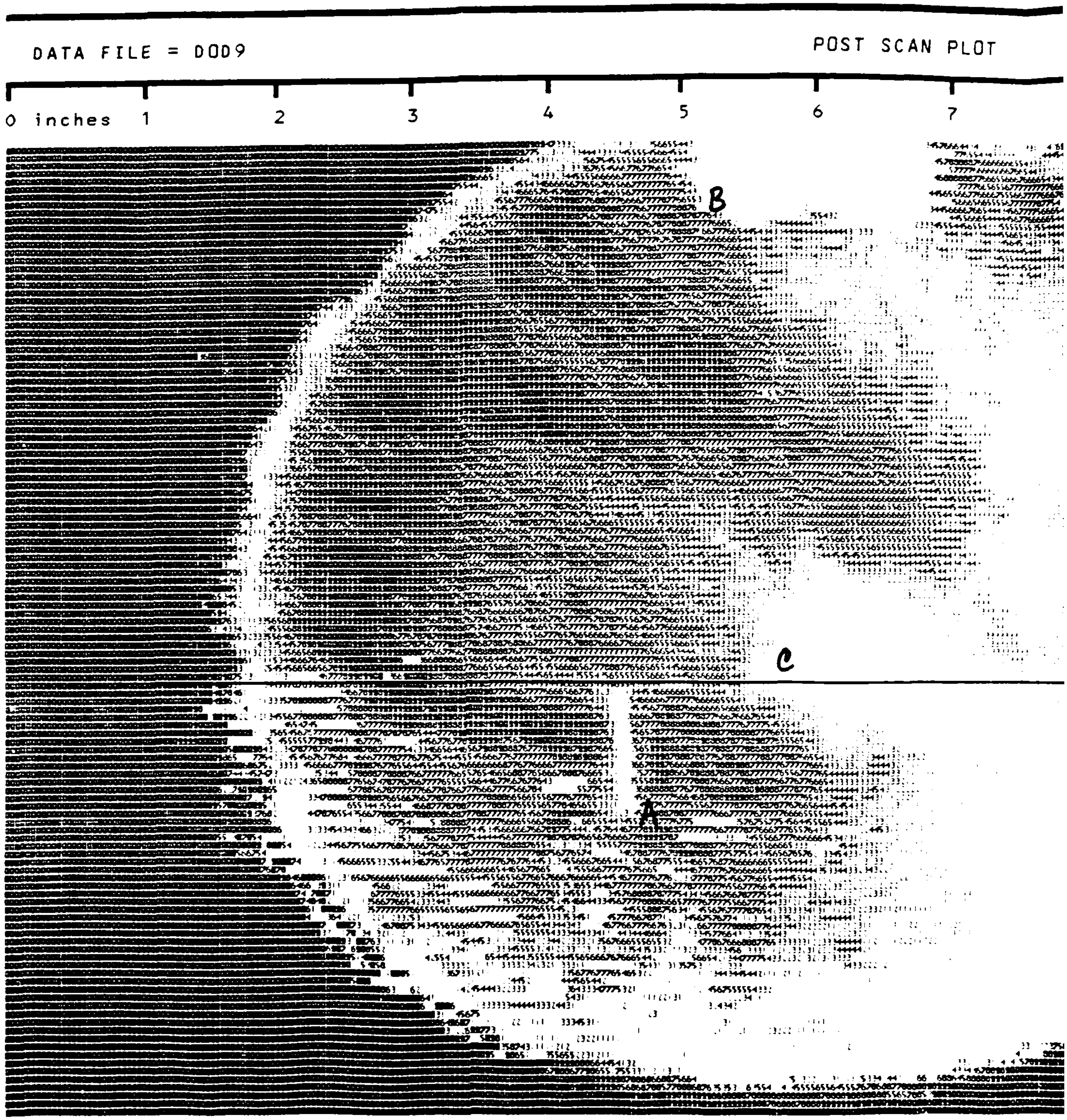

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4-B

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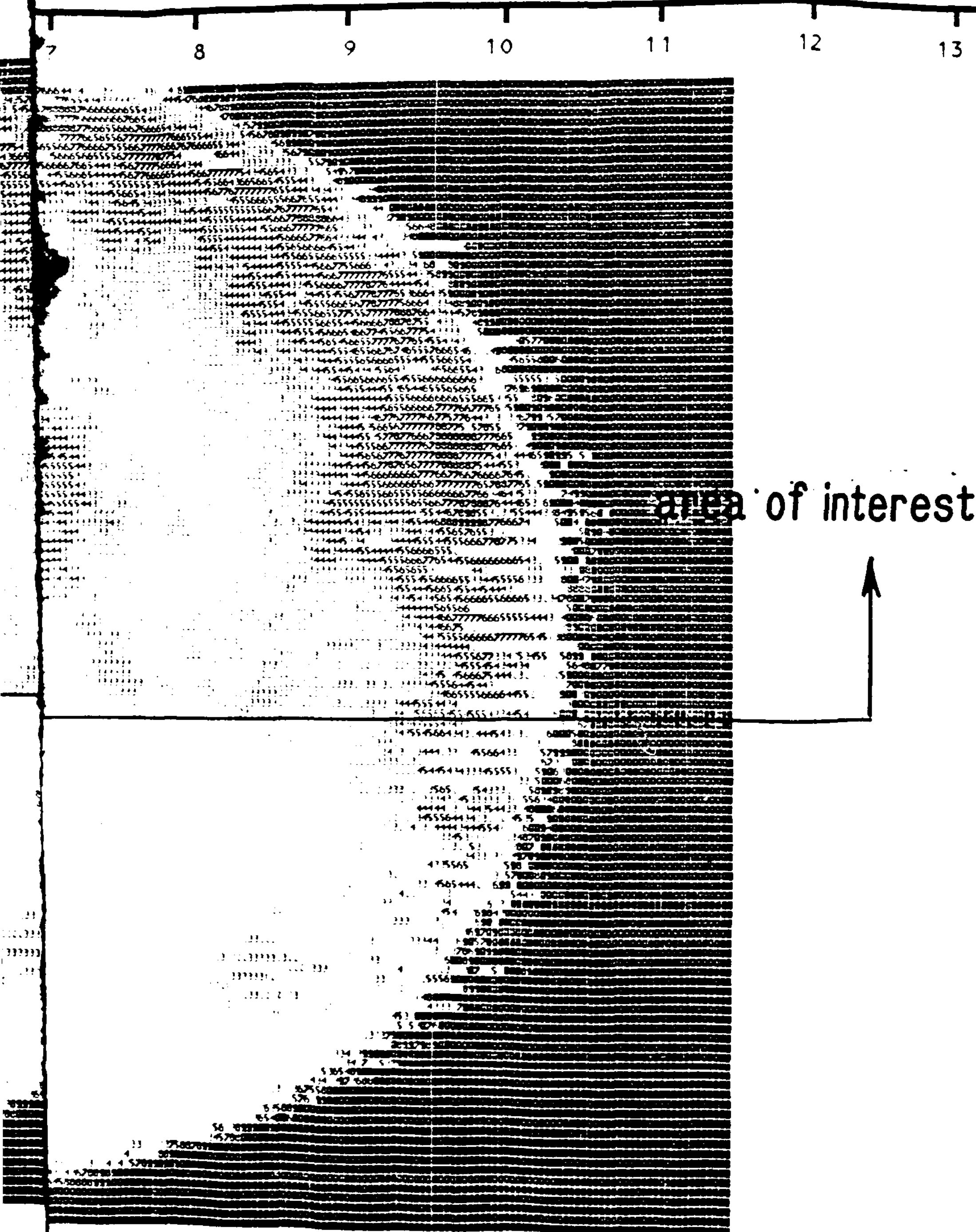

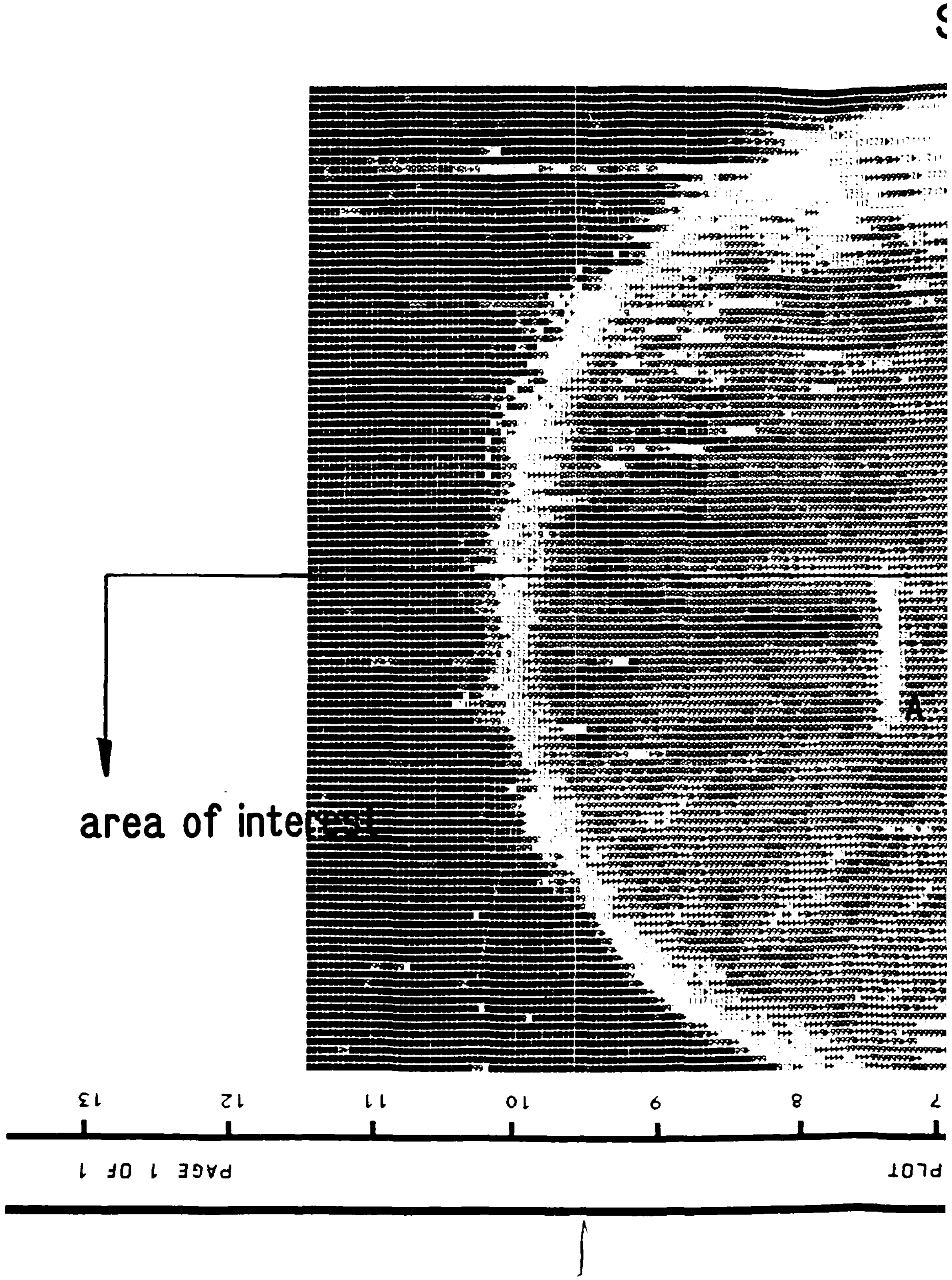

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PAGE 1 OF 1
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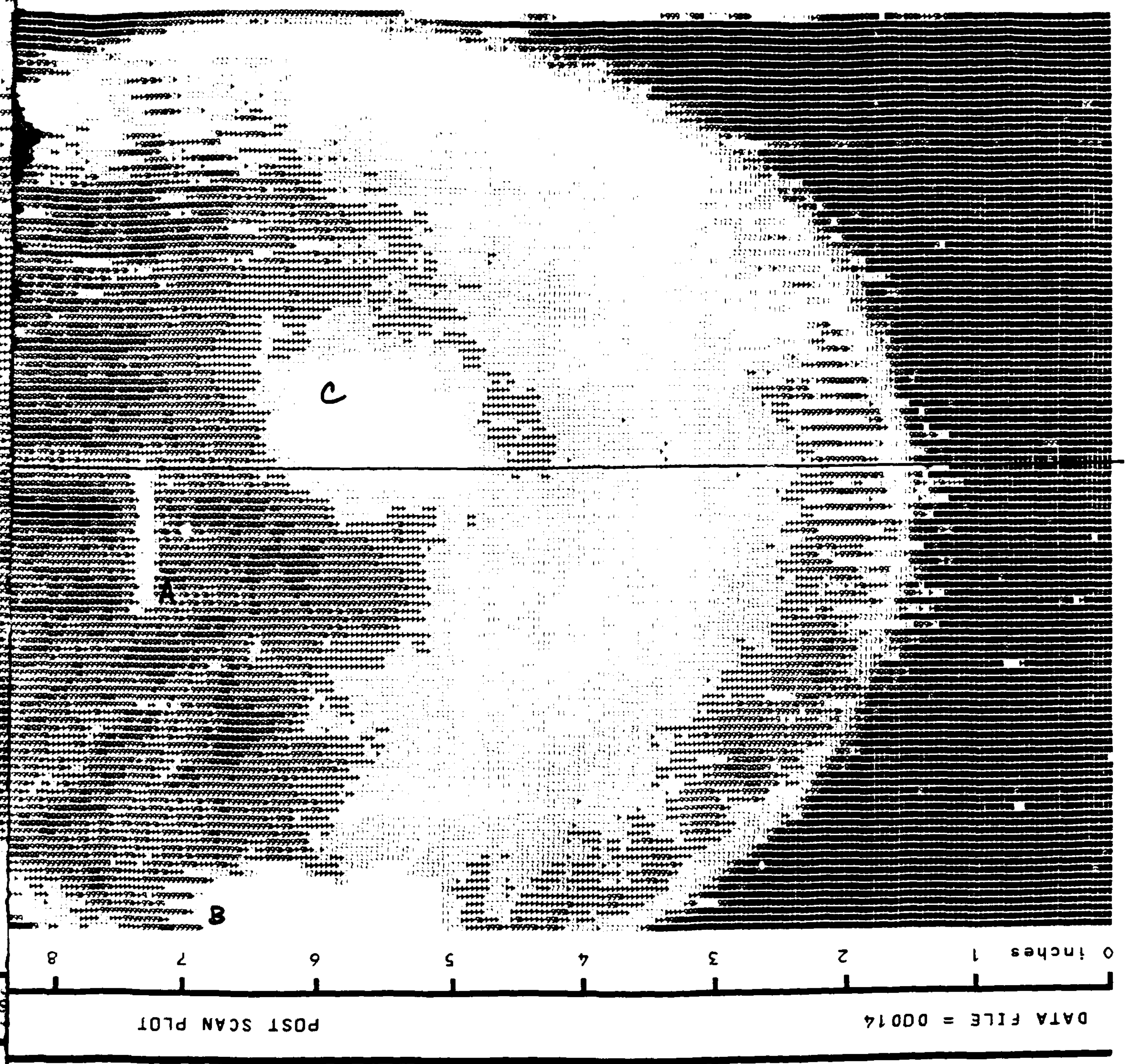
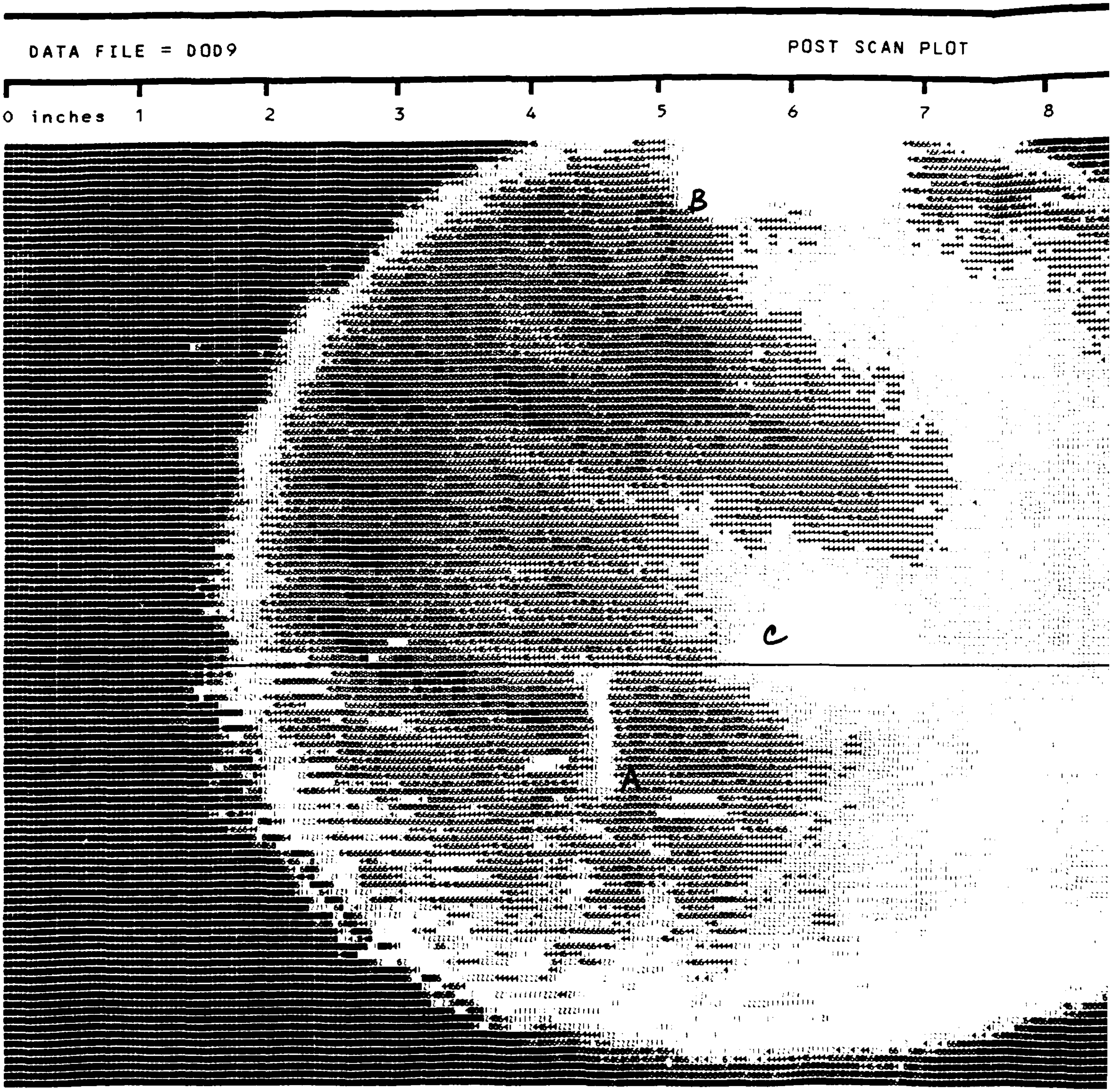
SAMPLE NO. 4





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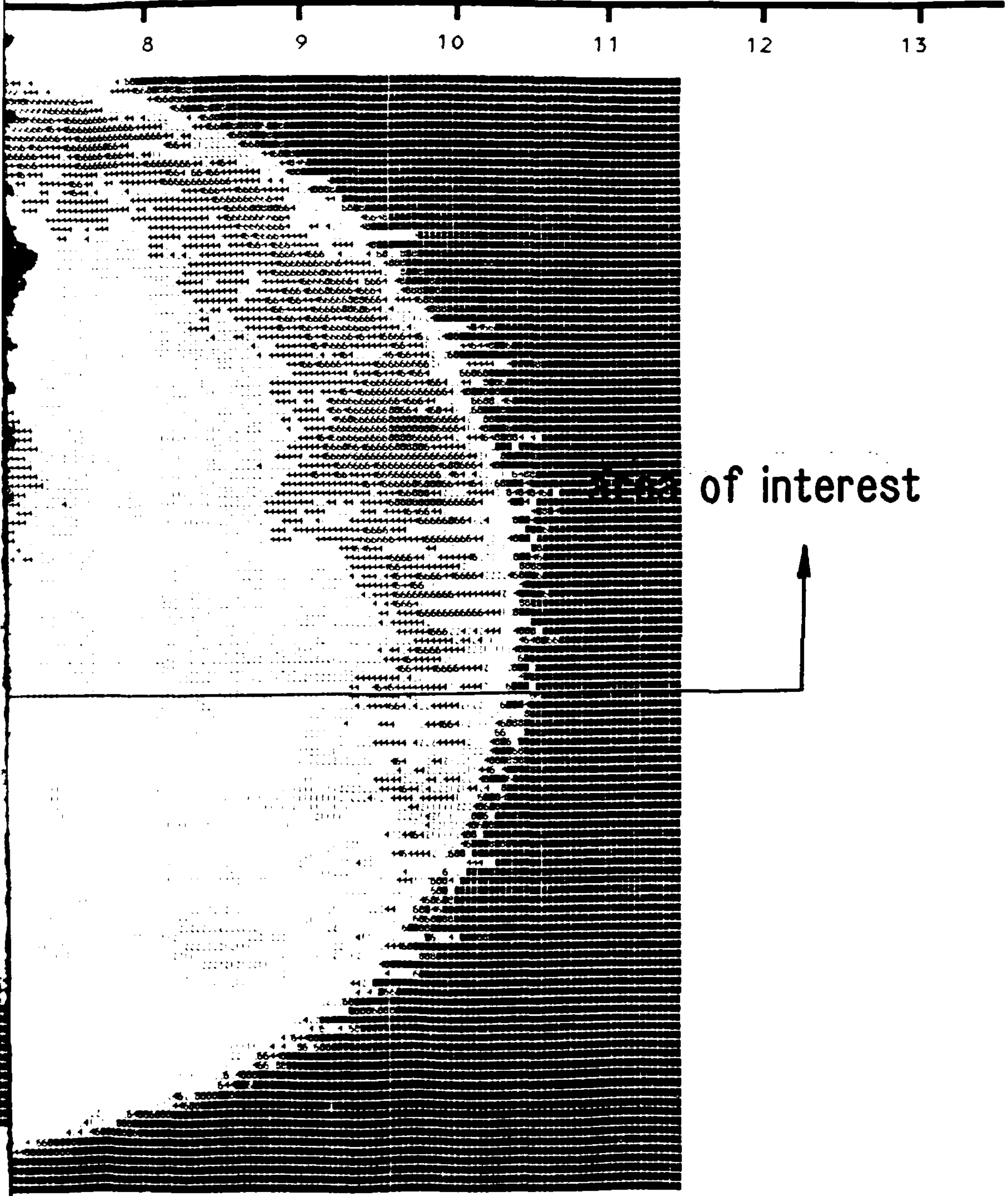

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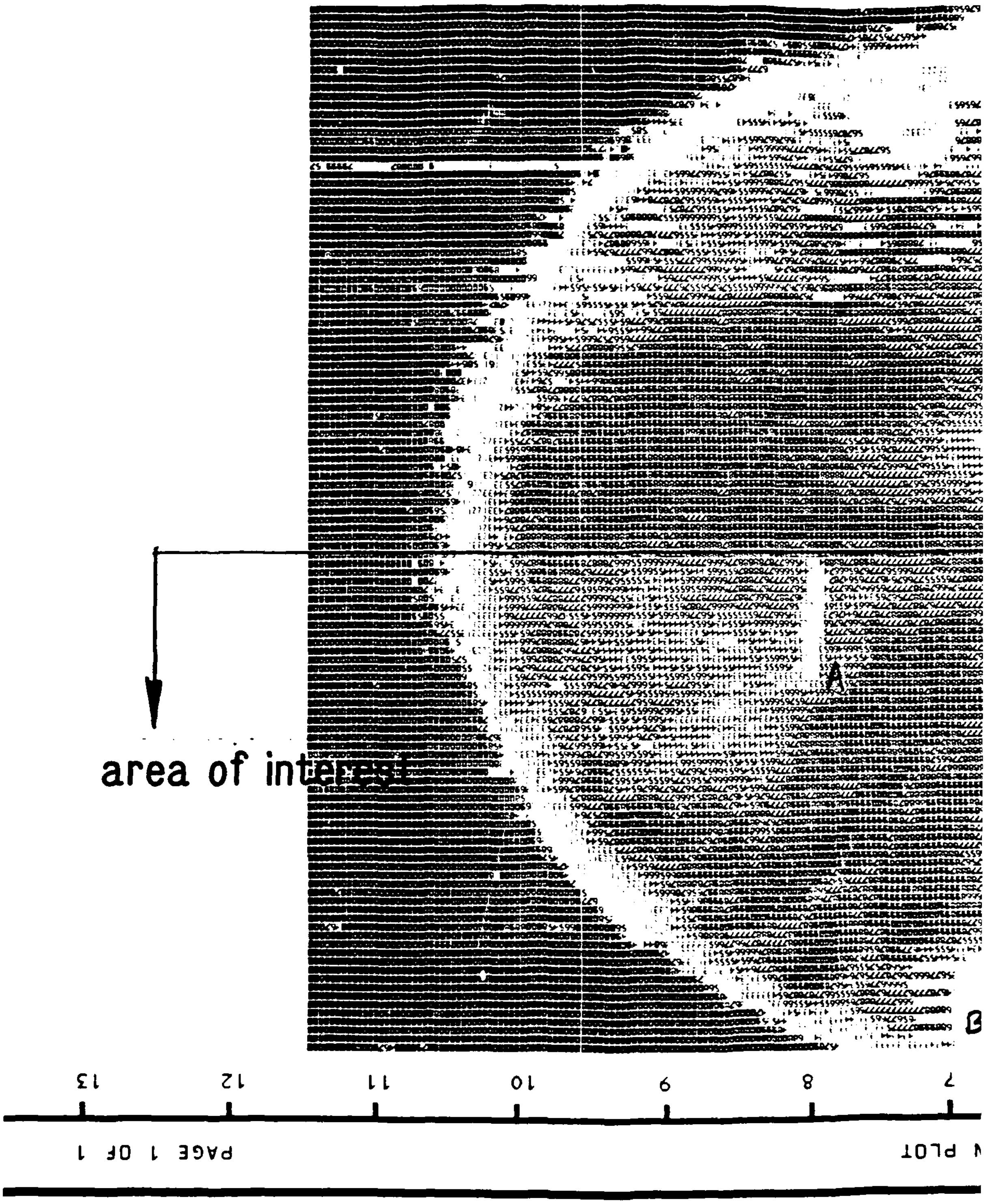

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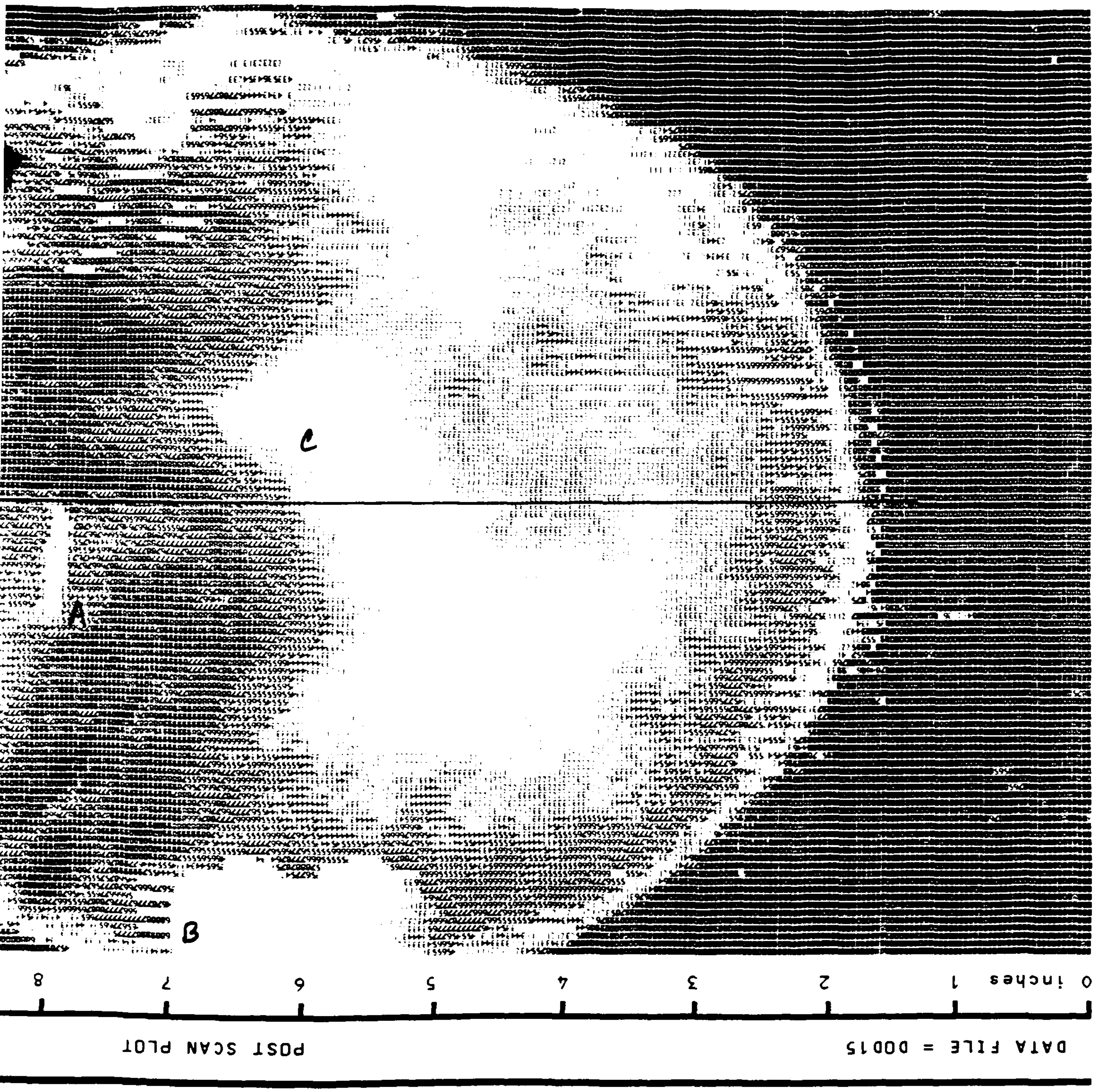

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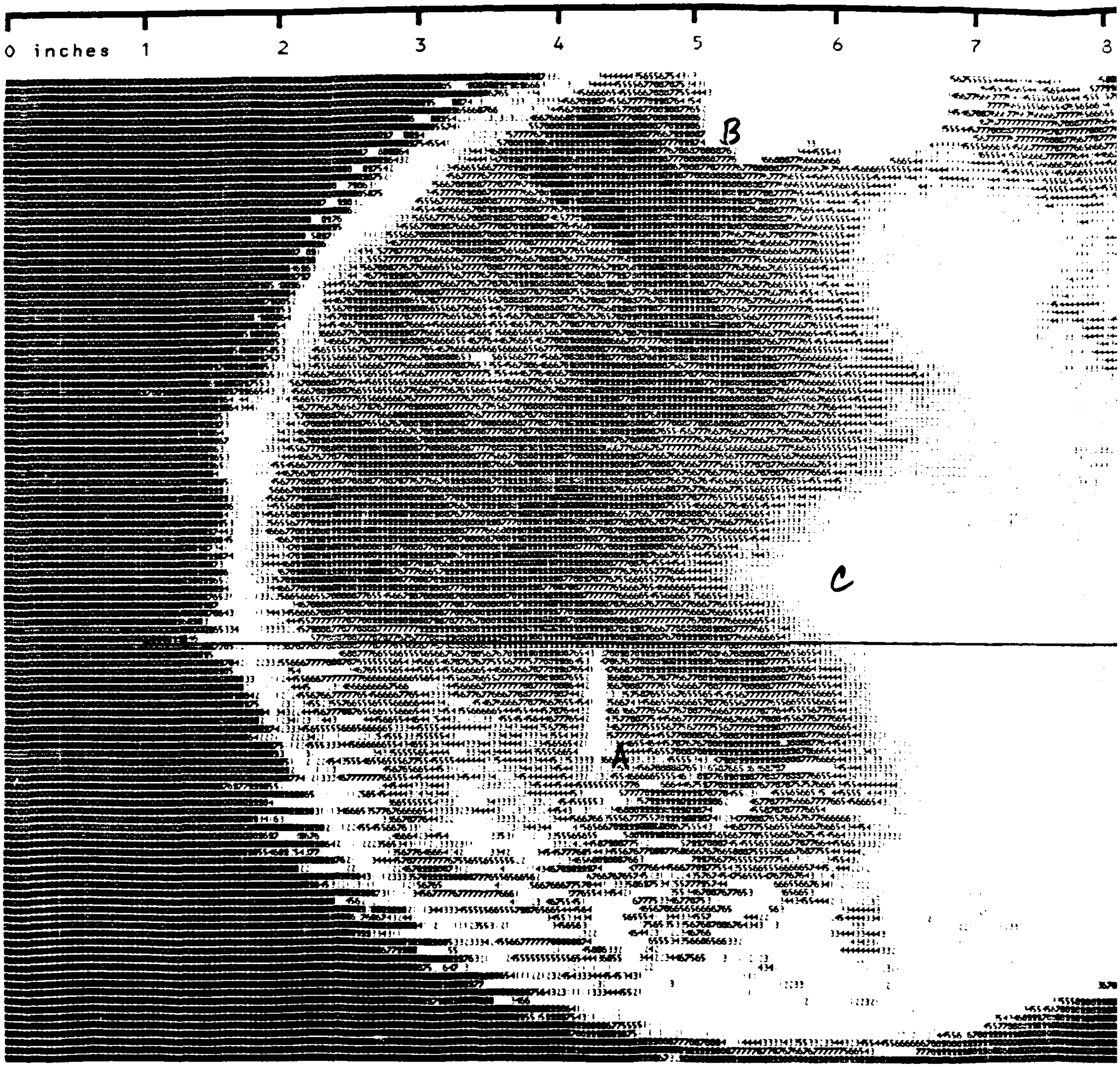

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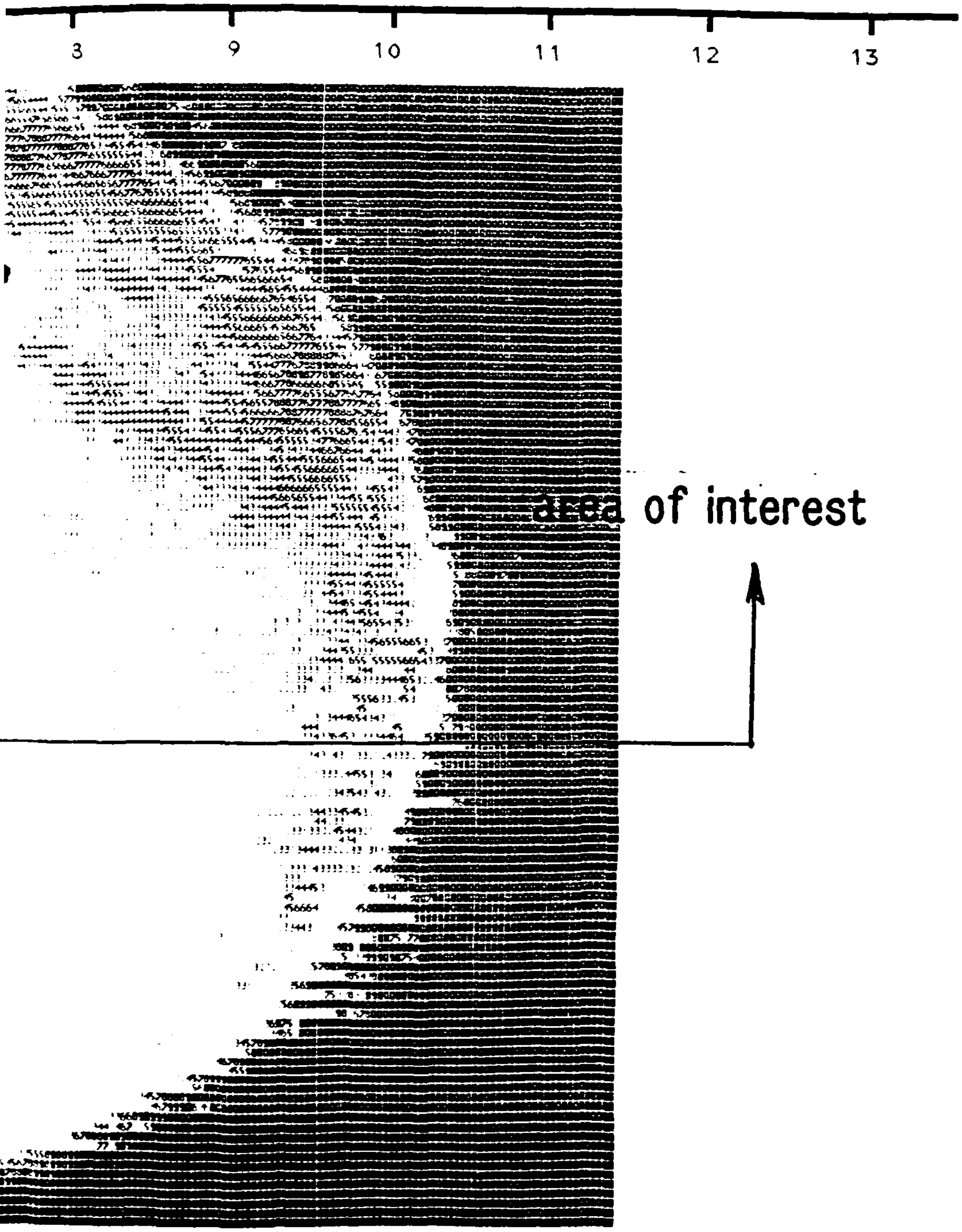
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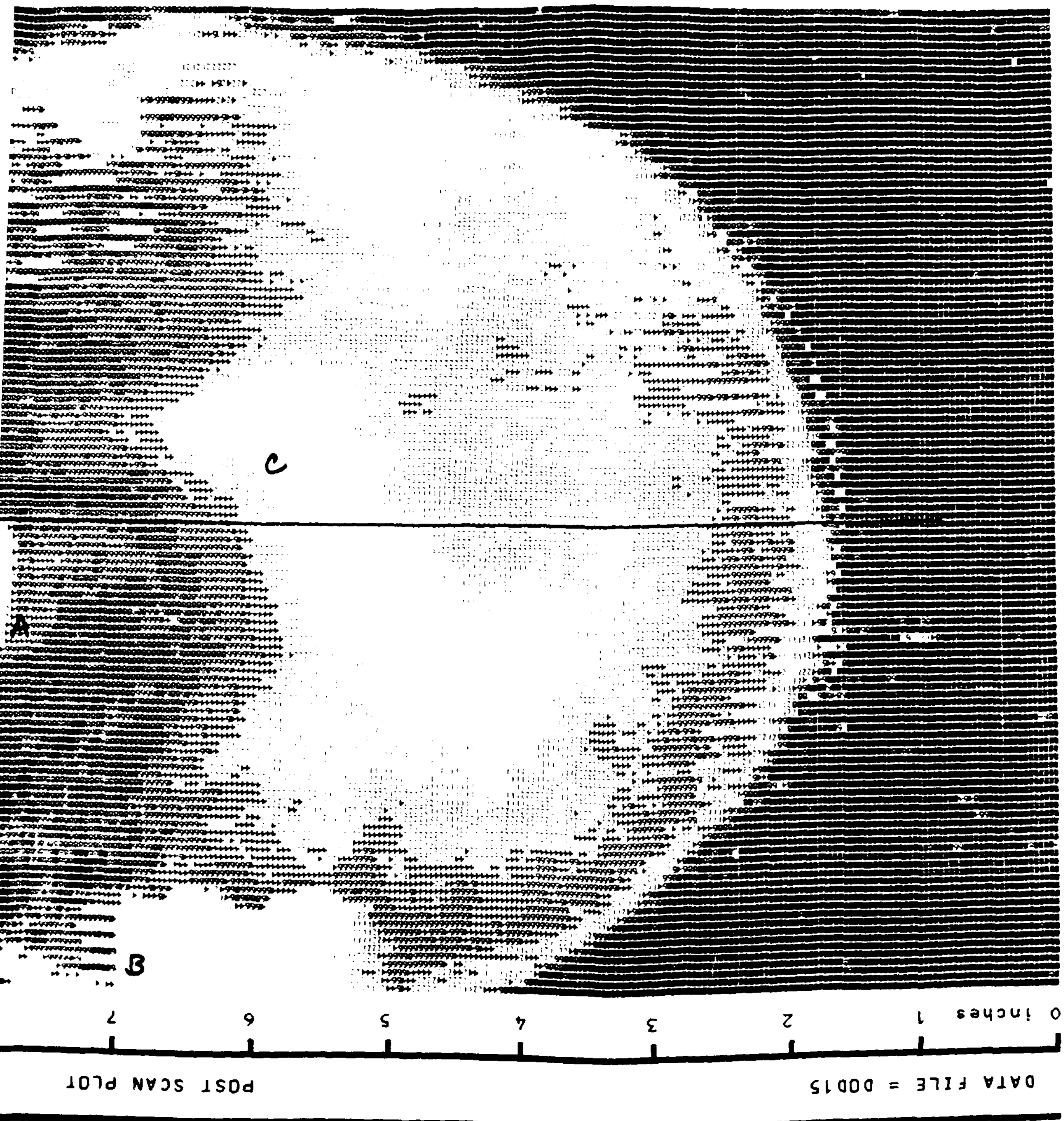

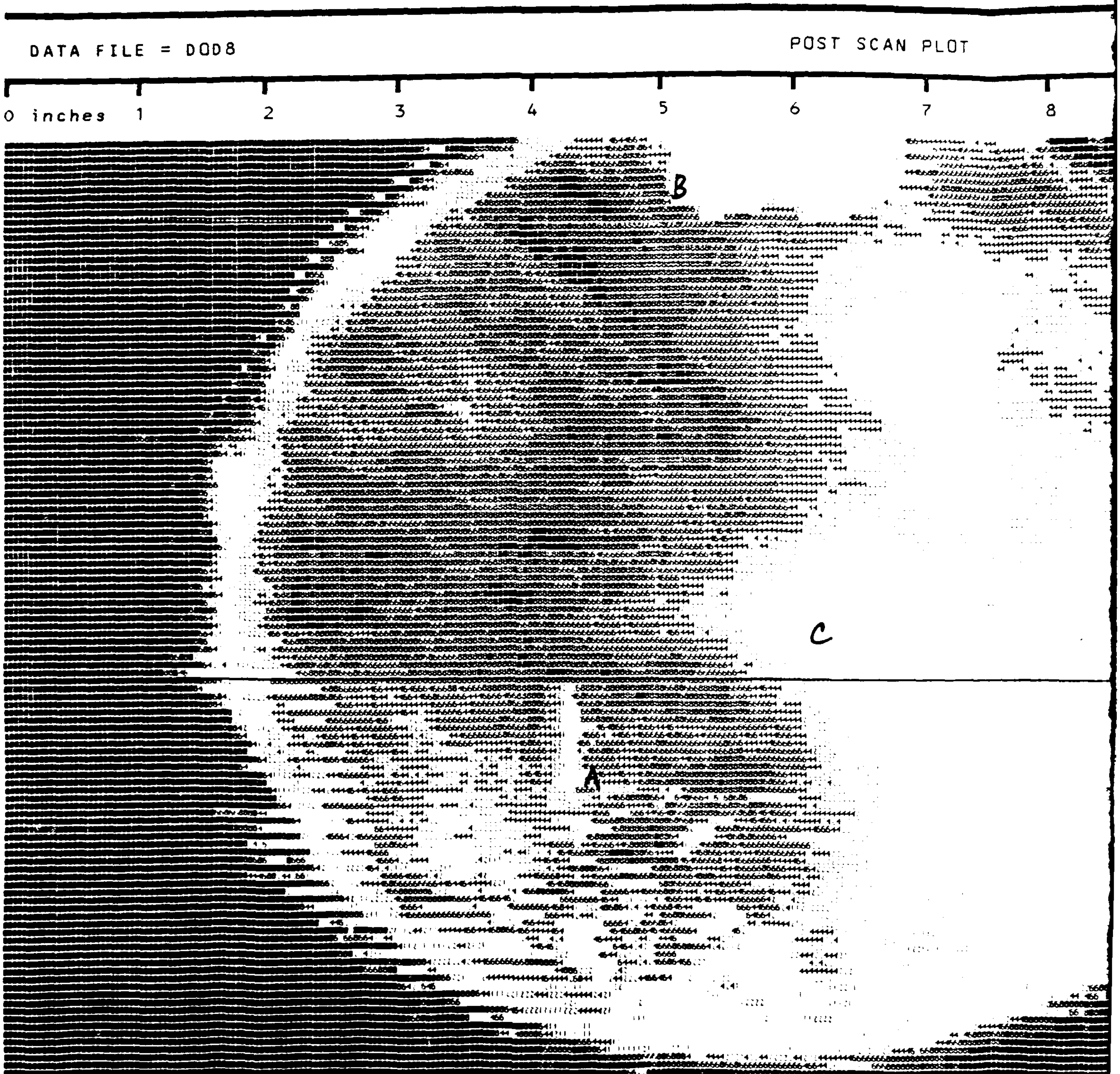

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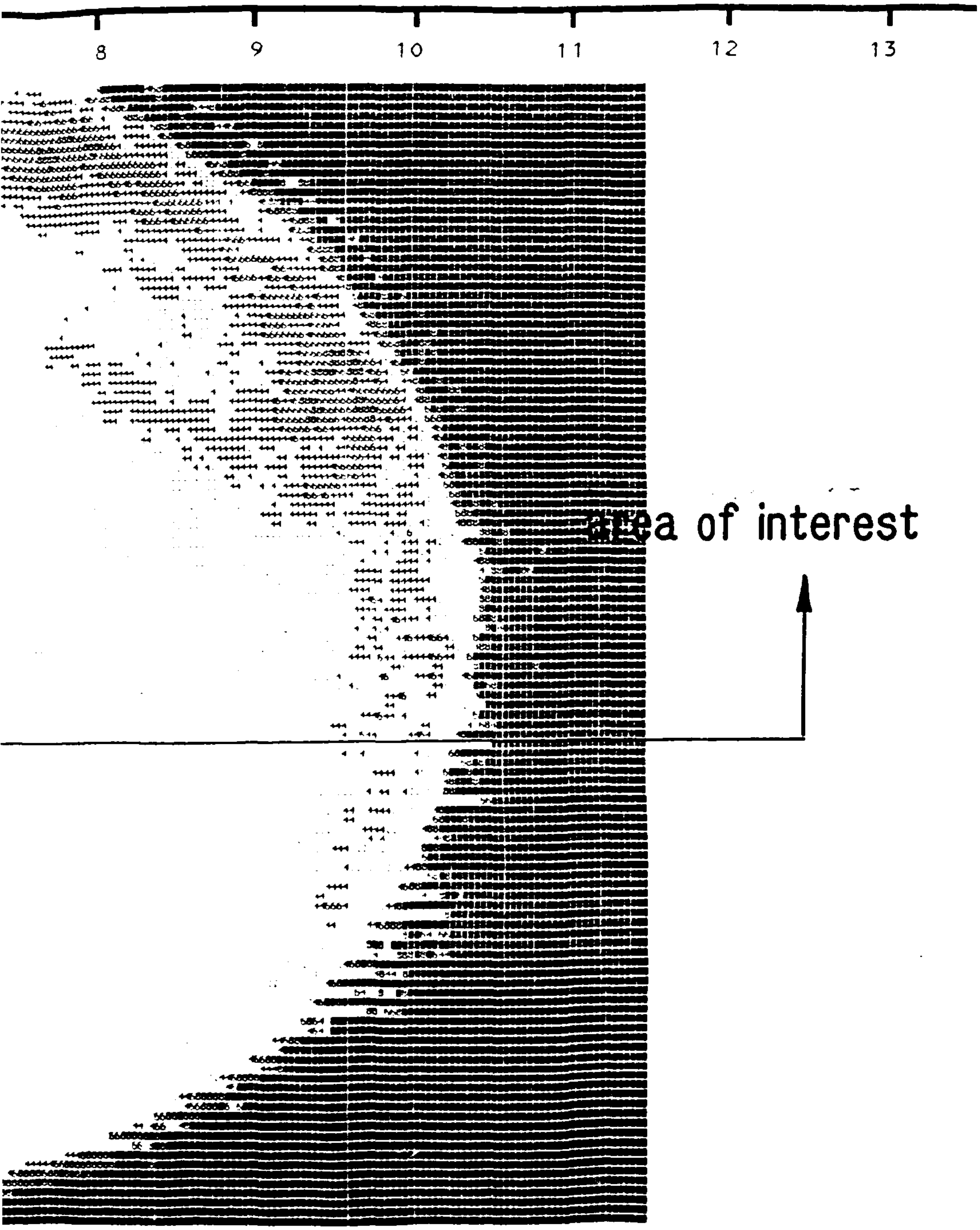
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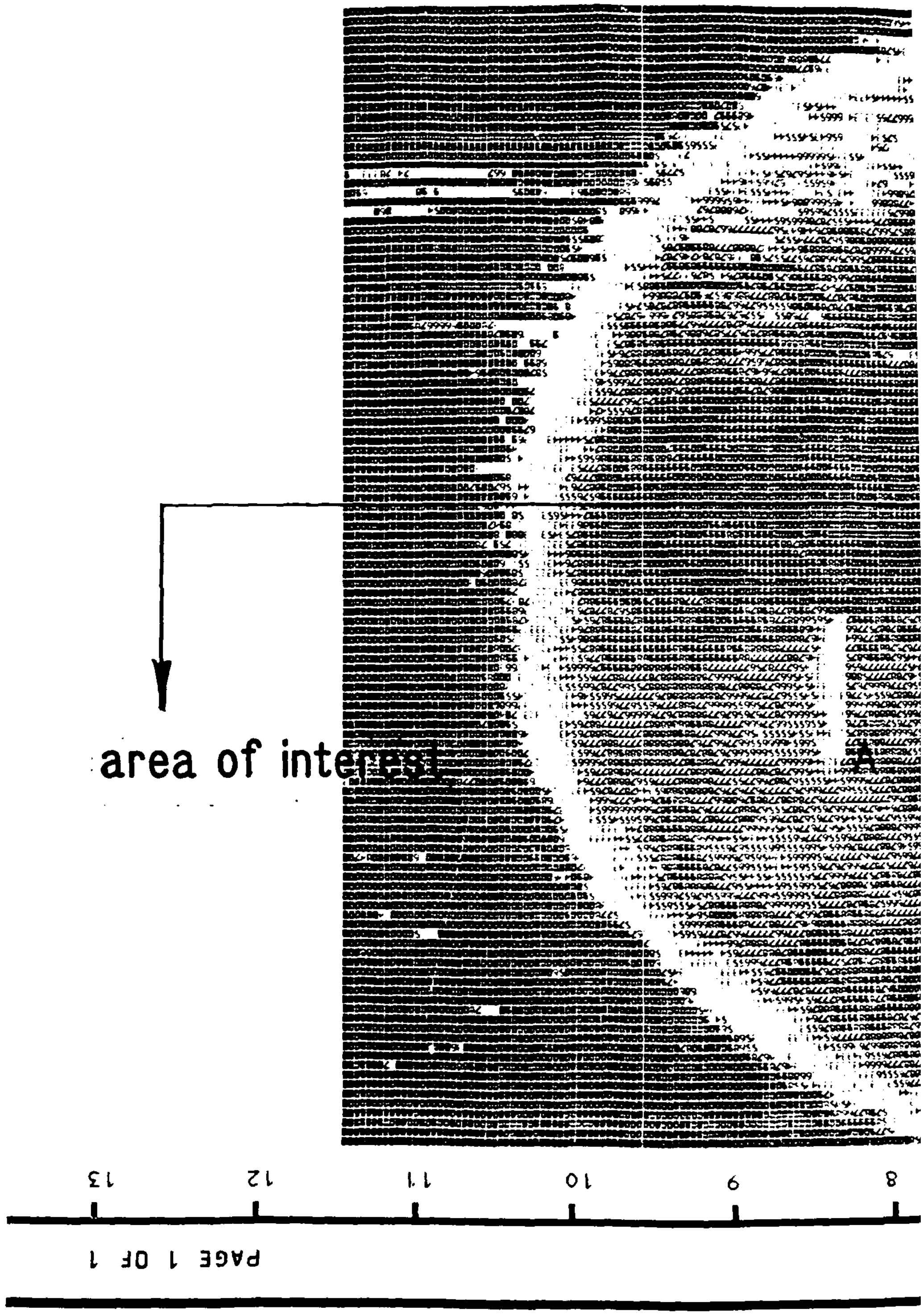
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PAGE 1 OF 1

6-A

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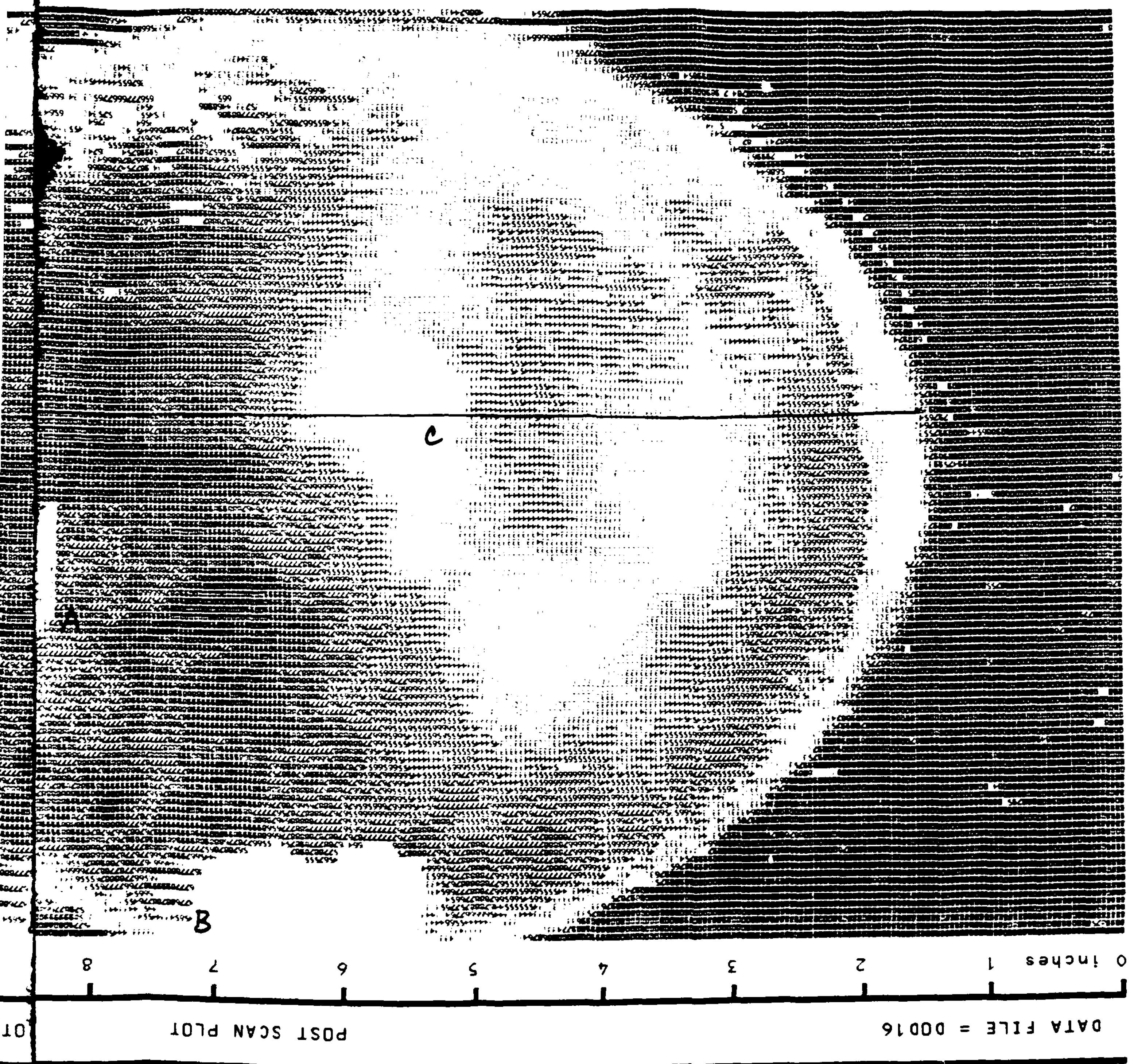

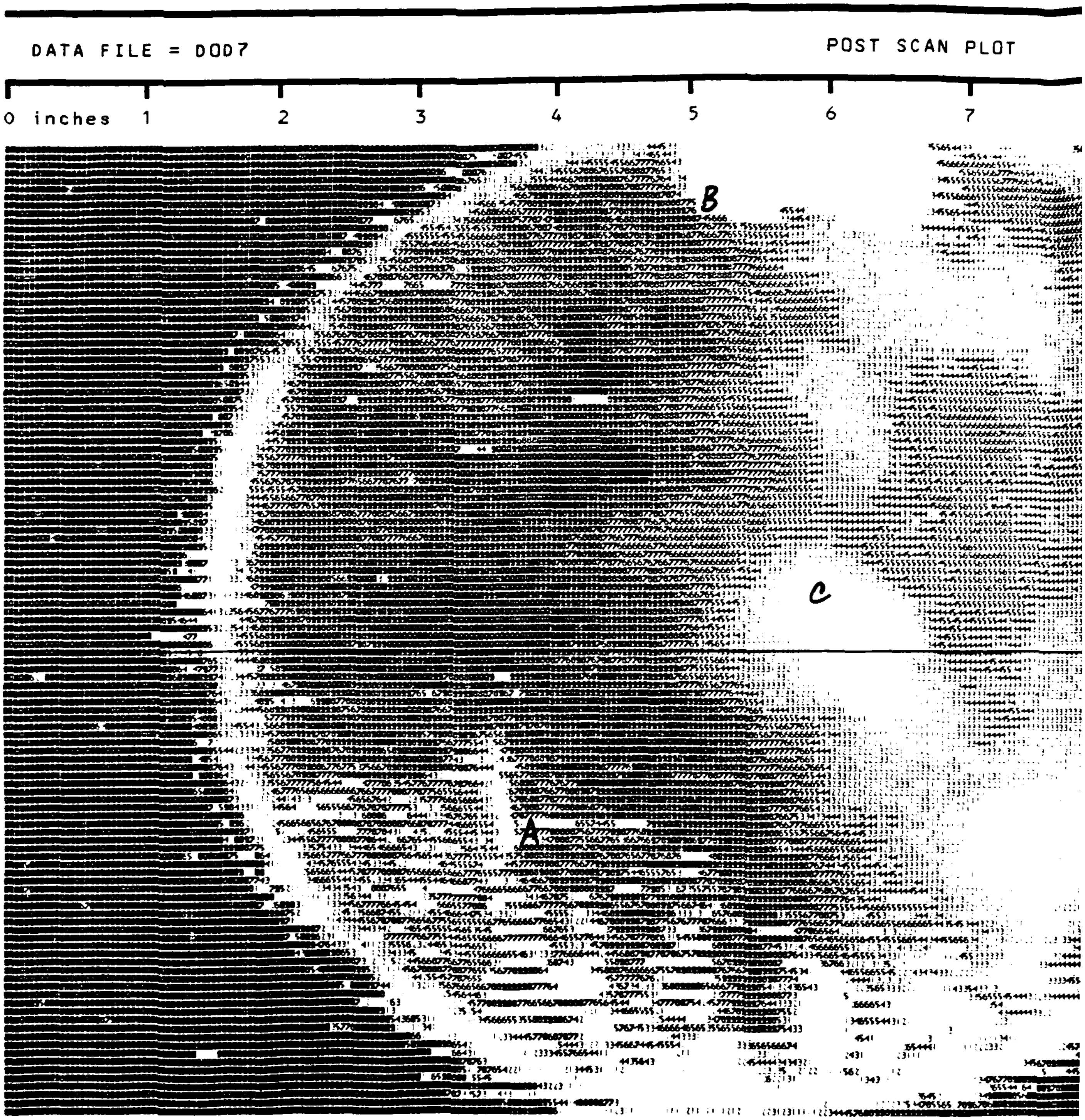

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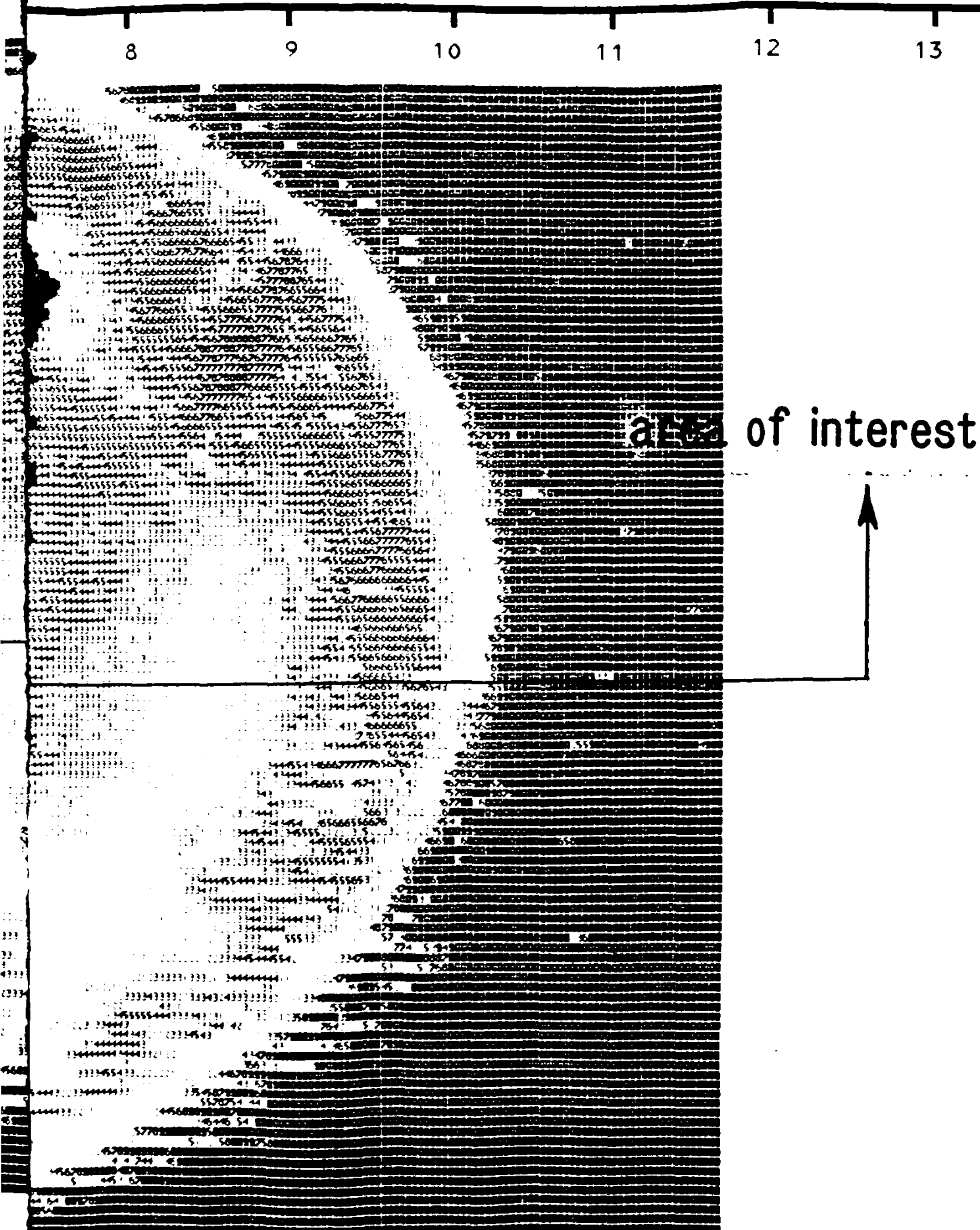
6-B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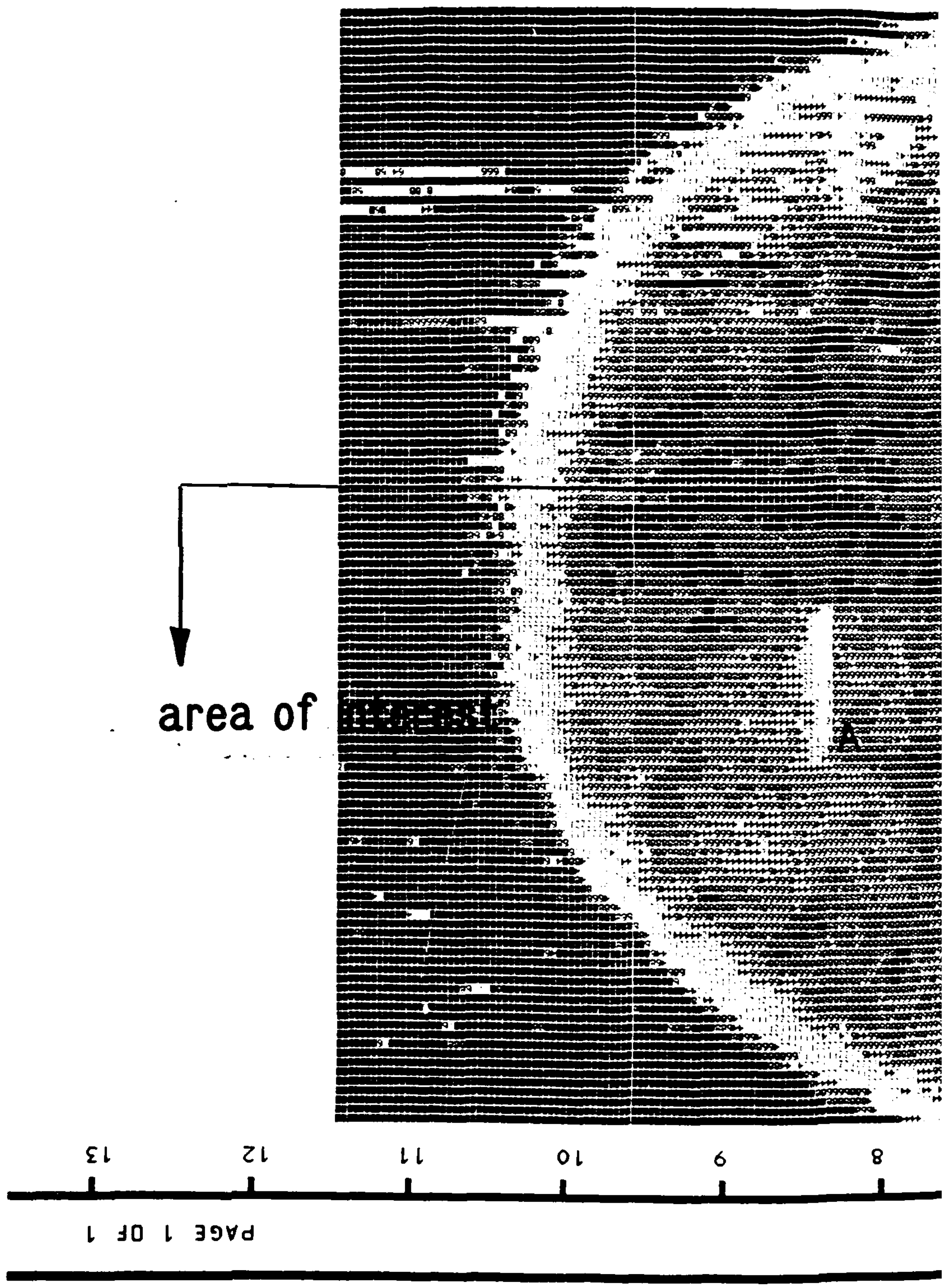

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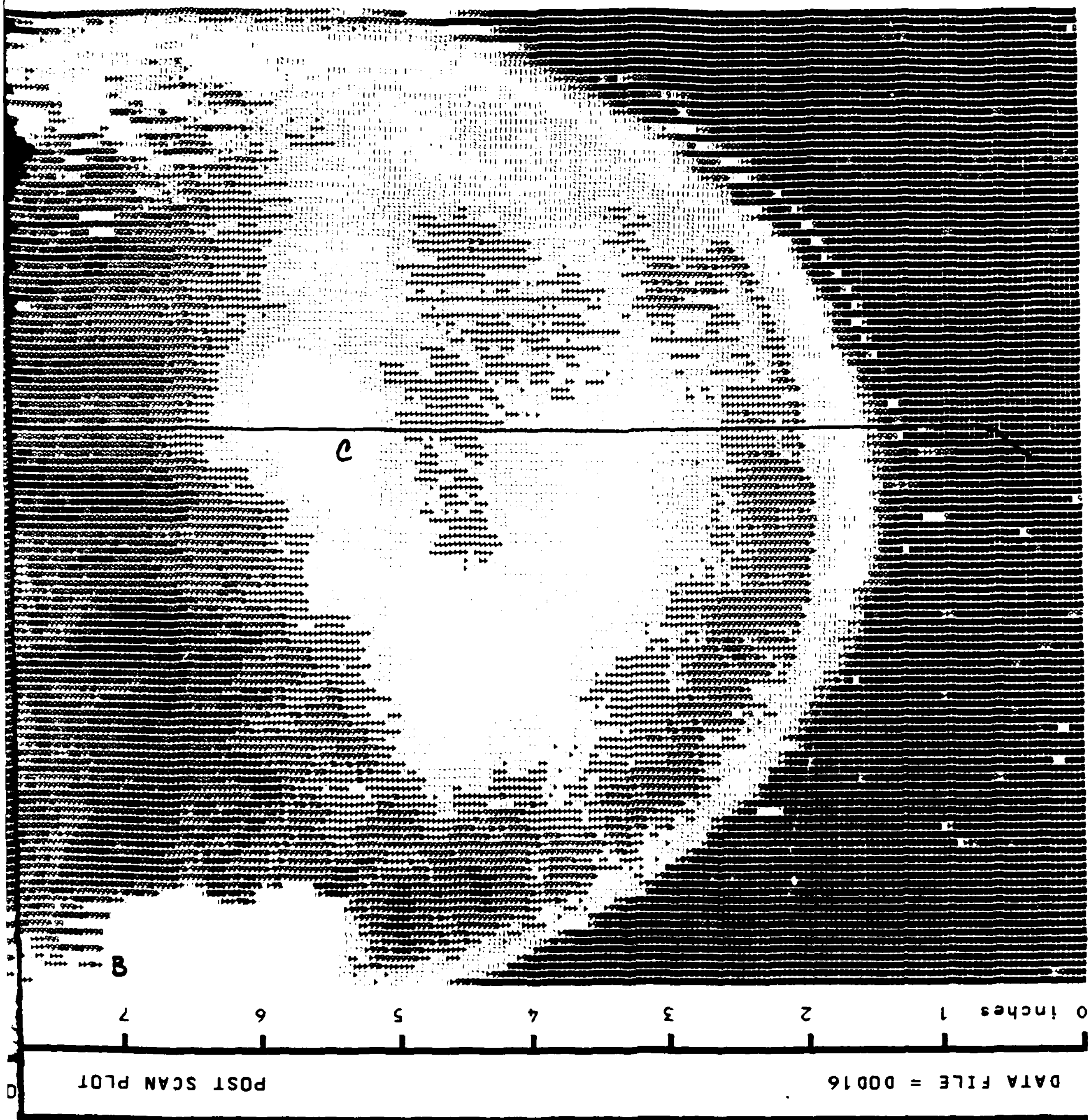

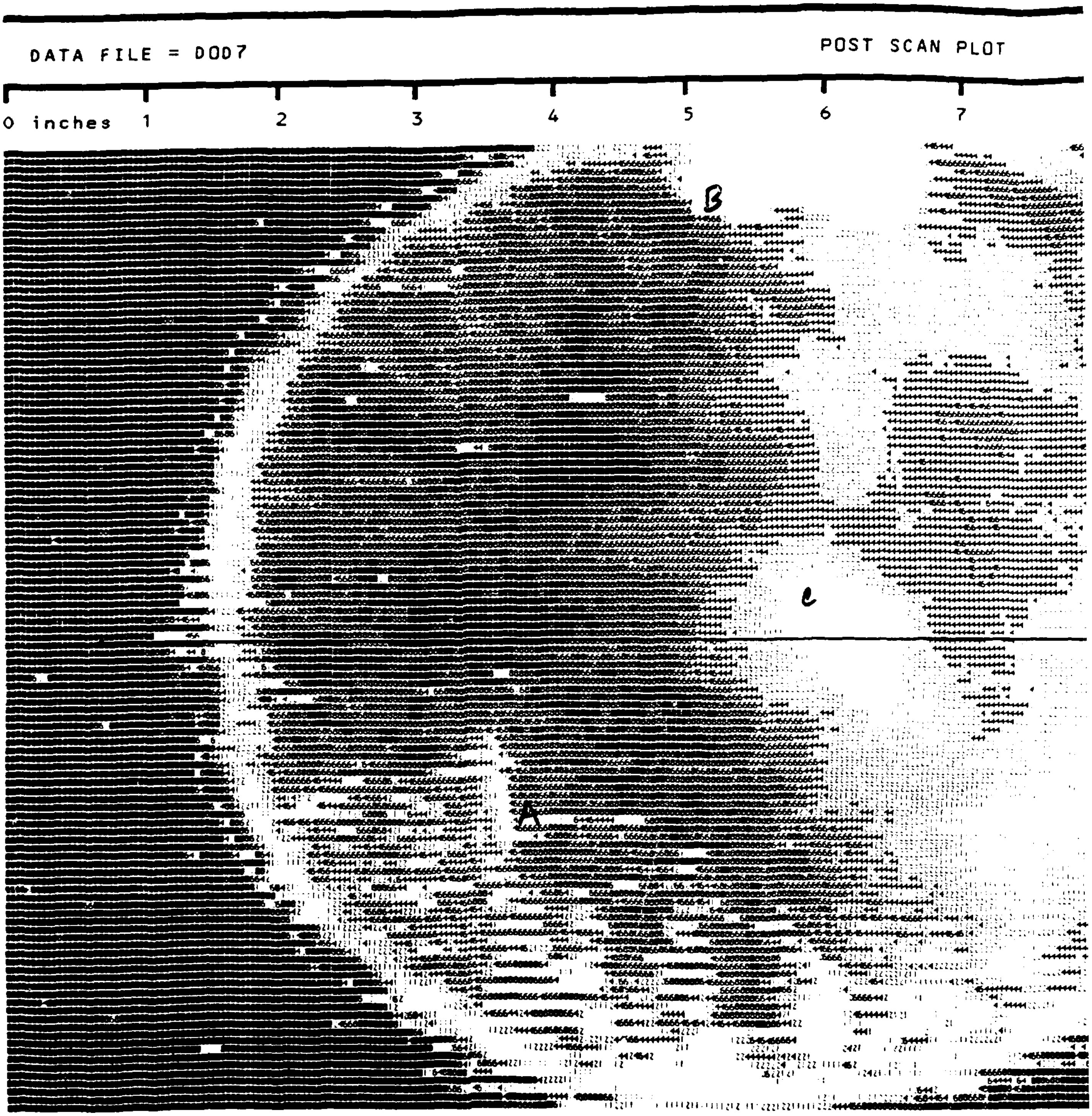

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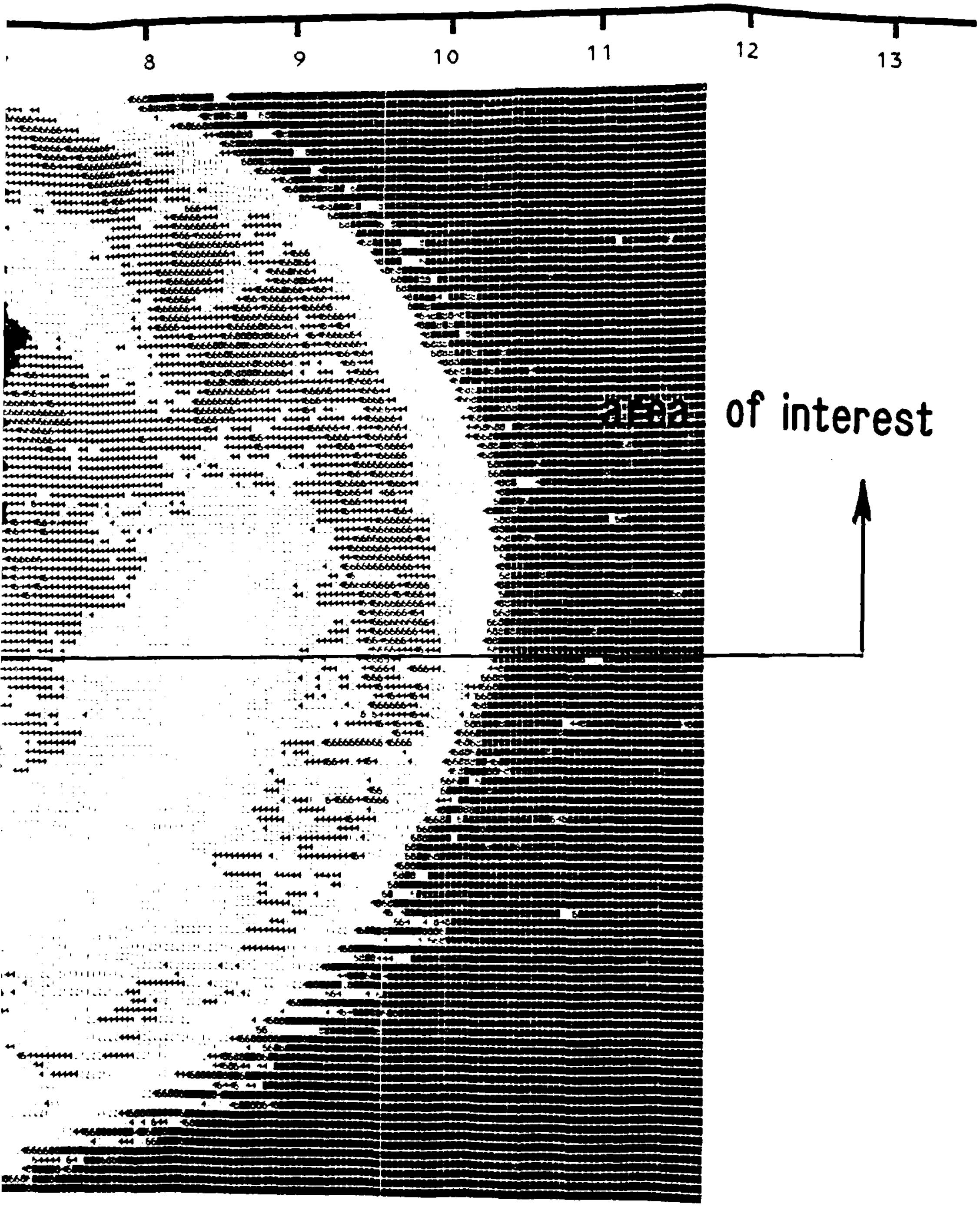
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